SITE CHARACTERIZATION/REMEDIAL INVESTIGATION REPORT
AOI 8

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PHILADELPHIA REFINERY
PHILADELPHIA, PENNSYLVANIA

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January 31, 2012
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1.0 INTRODUCTION

Sunoco Inc. (R&M) (Sunoco) and the Pennsylvania Department of Environmental Protection (PADEP) entered into a Consent Order & Agreement (CO&A) in December 2003 with respect to Sunoco's Philadelphia Refinery (refinery). Sunoco's Phase I Remedial Plan (Phase I Plan), dated November 2003, was included as an attachment to the CO&A. In accordance with the CO&A and Phase I Plan, a Current Conditions Report and Comprehensive Remedial Plan (CCR) was prepared by Sunoco in June 2004. The Phase I Plan and the CCR divided the facility into 11 Areas of Interest (AOIs), and presented a prioritization of the AOIs based on specific risk factors. The AOIs are shown in Figures 1 and 2 of this report. The CCR also presented the Phase II remedial approach and schedule to characterize each of the 11 AOIs, and to conduct Phase I and II corrective action activities in accordance with the 2003 CO&A and the Phase I Plan. Since 2003, Sunoco has completed site characterization activities at eleven AOIs (AOIs 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, and 11). For each AOI that has been characterized, Sunoco has prepared and submitted a corresponding Site Characterization Report (SCR) in accordance with the Revised Phase II Corrective Action Activities schedule that was included in the CCR.

Sunoco submitted a Site Characterization Work Plan (Work Plan) for AOI 8 on May 16, 2008 to the PADEP and United States Environmental Protection Agency (EPA). This Work Plan summarized proposed activities to be completed to characterize AOI 8 in accordance with the objectives of the CCR. The Work Plan also included proposed activities to characterize the Resource, Conservation and Recovery Act (RCRA) Solid Waste Management Unit (SWMU) in AOI 8. The Work Plan was implemented between May and August 2008 and the results were summarized in a SCR submitted to PADEP and EPA on September 30, 2008. A PADEP technical response comment letter, dated November 14, 2008, was received by Sunoco in response to the SCR. In 2009, additional site characterization work was performed to address PADEP comments in the November 14, 2008 comment letter.

This report is a combined Site Characterization/Remedial Investigation Report (SCR/RIR) which summarizes the site characterization work completed in 2008 and 2009. This SCR/RIR is being submitted to the PADEP and EPA in accordance with the provisions of Pennsylvania's Land Recycling and Environmental Remediation Standards Act (Act 2).

In accordance with Act 2, Langan, on behalf of Sunoco, has prepared the required public and municipal notices as part of this report submittal. The notices and their proof of receipt/publication are included in Appendix A of this report.

1.1 Site Description

The Sunoco Philadelphia Refinery is located in southwest Philadelphia. AOI 8 is the northern most area of the refinery and is known as the Point Breeze Process Area North Yard. AOI 8 is bound by the Philadelphia Gas Works (PGW) property to the south, the Schuylkill River to the west, industrial properties to the north, and urban streets to the east (Figures 1 and 2), and encompasses approximately 250 acres.

1.2 Site History

The facility has a long history of petroleum transportation, storage, and processing. The oldest portion of the facility started petroleum related activities in the 1860's, when the Atlantic Refining Company was established as an oil distribution center. In the 1900's, crude oil processing began and full-scale gasoline production was initiated during World War II. In addition to refining crude oil, various chemicals, such as acids and ammonia, were also produced at the site for a time. Current operations at the refinery are limited to the production of fuels and basic petrochemicals for the chemical industry. The current and historic uses of AOI 8 are described on figures provided in Appendix B.

AOI 8 was an active refinery process area since the early twentieth century with process areas and above ground storage tanks (ASTs). The area also included the former lube, asphalt, soap, and wax plants. The majority of AOI 8 structures were demolished between 1975 and 1980. Subsequent to decommissioning of the process areas, a Land Treatment Unit ("LTU") was operated from 1986 through 2000. Currently, the only remaining active facilities in AOI 8 are the asphalt dock, the boiler house, a storm water separator, fuel oil storage, butane and propane storage area, and loading and unloading facilities. Much of AOI 8 is unimproved and many of the ASTs have been demolished. The majority of the land surface in AOI 8 is not covered by impervious surfaces.

1.3 Selection of Compounds of Concern and Applicable Standards

The COCs for soil and groundwater are listed in Table 1 of this report. The COCs for the ongoing and proposed investigation activities include the current constituents from the Pennsylvania Corrective Action Process (CAP) Regulation Amendments effective December 1, 2001; provided in Chapter VI, Section E of PADEP's Closure Requirements for Underground Storage Tank Systems. These COCs are the same as those listed in the CCR. In May 2009, Sunoco included two additional COCs 1,2,4-trimethylbenze and 1,3,5-trimethylbenzene. These two compounds were added to the list of COCs by Sunoco based on the PADEP's revisions to the petroleum short list of compounds at the request of the PADEP, but are not part of the COC lists for soil and groundwater in AOI 8 because the site characterization work in AOI 8 was performed prior to these chemicals being added to the list.

Media of Concern

The media of concern for AOI 8 include groundwater and soil. The potential indoor air quality and off-site vapor migration exposure pathways were evaluated through the PADEP's vapor intrusion guidance. Surface water was evaluated as a receptor in relation to facility activities.

Act 2 Remediation Standards

The approach for attaining Act 2 remediation standards for the media of concern is described below by media.

Groundwater

Groundwater sample results were screened against the PADEP non-residential, used-aquifer (TDS<2,500) statewide health groundwater medium-specific concentrations (MSCs). As summarized in the CCR, where constituent concentrations are above these statewide health MSCs, Sunoco evaluated application of the site-specific remediation standard using either the pathway elimination or calculated risk-based standard options.

Shallow Soil – 0 to 2 Feet Interval

Shallow (0-2 feet) soil samples were collected at each soil boring/monitoring well location that represents a potential complete direct contact exposure pathway to site workers (e.g., unpaved areas). These shallow soil results were screened against the PADEP non-residential soil MSCs. Where constituent concentrations are above the PADEP non-residential soil MSCs, Sunoco evaluated application of the site-specific remediation standard using either the pathway elimination or calculated risk-based standard options.

Soil – 2 to 15 Feet Interval

A site-specific remediation standard using the pathway elimination option was applied for soil between 2 and 15 feet beneath the ground surface within the boundaries of AOI 8 based on Sunoco's existing permit program governing excavations. This permit program serves as an institutional control that prevents potential exposure to impacted soils greater than two feet beneath the ground surface. Soil at this depth is evaluated through the groundwater data.

Vapor Intrusion into Indoor Air

For the current occupied buildings in AOI 8 as depicted on Figure 2, groundwater is less than five feet below the ground surface; therefore, the PA DEP USEPA-PA Default Non-Residential Permissible Exposure Limit (PEL) for Volatilization to Indoor Air for soil and groundwater screening criteria in the PADEP's guidance could not be used. As part of the Cleanup Plan for AOI 8, further evaluation (i.e., soil gas samples) will be necessary to assess the impact to indoor air. Because the site specific standard is being used for the Facility, groundwater within some portions of AOI 8 is shallower than five feet, underground utilities exist and sampling was not completed below areas with impervious covers, Sunoco will place a restriction in the Uniform Environmental Covenants Act (UECA covenant) for AOI 8 that will require further vapor site characterization activities and/or installation of a vapor mitigation systems for any new occupied buildings that will be constructed within AOI 8.

1.4 Overview of Investigative Framework and Remedial Approach for AOI 8

The current remediation program for the refinery is performed under the 2003 CO&A between PADEP and Sunoco. Below is a general summary of the regulatory frame work for the refinery:

- In April 2004, the PADEP and EPA signed an agreement entitled "One Cleanup Program Memorandum of Agreement (MOA or One-Cleanup Program)," which clarifies how sites remediated under Pennsylvania's Act 2 program may satisfy RCRA corrective action requirements through characterization and attainment of Act 2 remediation standards pursuant to Pennsylvania's Act 2.
- In 2005, PADEP, EPA, and Sunoco agreed that the One Cleanup Program would benefit the project by merging the remediation obligations under the various

programs into one streamlined approach which would be conducted under the existing 2003 CO&A.

- In October 2006, Sunoco submitted a notice of intent to remediate (NIR) to the PADEP for the refinery entering the refinery into the Act 2 program, excluding the Belmont Terminal. A copy of this NIR and the Act 2 report notifications for this SCR/RIR/Cleanup Plan are included in Appendix A.
- In September 2007, Sunoco held a public involvement meeting in South Philadelphia, Pennsylvania.
- On November 8, 2011, the EPA provided an acknowledgment letter to Sunoco formerly accepting the Sunoco Philadelphia Refinery into the One Clean Up Program. EPA acknowledges that Sunoco is currently operating under the one EPA ID Number (PAD049791098) for Point Breeze, Girard Point and Schuylkill River Tank Farm. EPA will issue a letter to Sunoco for each characterized SWMU that lists a non-leaded tank bottom designation for which no further action is required.
- On November 30, 2011, Sunoco submitted a revised *Work Plan for Sitewide Approach Under the One Cleanup Program* (Work Plan for Sitewide Approach), to document the Sitewide remedial approach extending beyond the requirements of the 2003 CO&A. DEP and EPA have reviewed and provided input to this report. With this work plan Sunoco submitted a letter of commitment stating Sunoco will remediate the Philadelphia refinery site according to the Work Plan for Sitewide Approach.

1.4.1 Overview of the Land Farm Treatment Unit (LTU) in AOI 8

The LTU is located in the northwestern portion of AOI 8 and encompasses approximately 20 acres. RCRA closure of the LTU was completed in 2005 and the unit is currently undergoing RCRA Closure and Post-Closure monitoring activities in accordance with a separate 1996 CO&A. Therefore, no characterization work was undertaken at the LTU as part of this site characterization. A description of the LTU is included in the Amended Post-Closure Plan (original dated November 1988 and amended May 2004).

2.0 ENVIRONMENTAL SETTING

AOI 8 is located in the northern most portion of the refinery and is also known as the North Yard. AOI 8 is bound by the PGW property to the south, the Schuylkill River to the west, industrial properties to the north and urban streets to the east (Figures 1 and 2). AOI 8 encompasses approximately 250 acres.

2.1 Historic and Current Use

AOI 8 was an active refinery process area since the early twentieth century with significant process areas and ASTs. The area also included the former lube, asphalt, soap, and wax plants. The majority of AOI 8 structures were demolished between 1975 and 1980. Subsequent to decommissioning of the process areas, the LTU was operated from 1986 through 2000.

Currently, the only remaining active facilities in AOI 8 are the asphalt dock, the boiler house, a storm water separator, fuel oil storage, butane and propane storage area, and loading and unloading facilities. Much of AOI 8 is unimproved and many of the ASTs have been removed. The majority of the land surface in AOI 8 is not covered by impervious surfaces.

Sheet pile and wooden bulkheads exist along the Schuylkill River as shown in Figure 2. The bulkheads extend along the Schuylkill River from the storm water separator south towards and including the active asphalt loading dock in the southwestern portion of AOI 8. The wooden portion of the bulkhead was constructed in the early 1930s and starts just south of the AOI 8 storm water separator and extends approximately 2,460 feet downstream. The southern 940 feet of the bulkhead is of newer steel sheet piling construction.

The 1991 RFI identified one SWMU in AOI 8 that required further characterization. This SWMU was identified as SWMU 2 containing leaded tank bottoms sludge and is located in the southwestern portion of AOI 8. This SWMU area was characterized during the site characterization activities and is described in further detail in Section 3.0 below.

The existing monitoring well network in AOI 8 includes a total of 174 monitoring points as listed in Table 2. This network includes those monitoring wells that were installed as part of the 2008 site characterization effort. The monitoring wells in AOI 8 are summarized in Table 2 and the remedial systems in AOI 8 are discussed in detail in Section 5.0. Sunoco samples select monitoring wells in AOI 8 for site COCs established in the CCR on an annual basis. Groundwater gauging of select monitoring wells in AOI 8 also occurs on an annual basis during the fourth quarter of each year. Annual gauging activities and groundwater results are reported to the PADEP and EPA in Quarterly Reports prepared by Sunoco.

Institutional controls (i.e. permits governing excavation, Occupation Safety and Health Administration (OSHA) restrictions, etc.) apply to AOI 8. These institutional controls limit exposure to hazardous site compounds of concern (COCs) as listed in Table 1. Prior to any work being completed within AOI 8, appropriate work permits, safety and security measures, etc. must be approved by refinery personnel. Operating areas of AOI 8 are located within a secured area to prevent unauthorized access. Direct contact to site soils (soils greater than two feet beneath the ground surface) is governed by Sunoco's on-site procedures and personal protective equipment (PPE).

2.2 Geology

To further characterize geology at AOI 8, Sunoco advanced 39 shallow and intermediate monitoring wells. Four deep soil borings were advanced to the top of bedrock. Each shallow, intermediate and deep boring was continually logged by a field geologist. To illustrate the geology at AOI 8, three geologic cross sections were prepared and are provided as Figures 5a, 5b and 5c in this report. The geologic cross section location lines are shown in Figure 4.

The following paragraphs describe the primary geologic units beneath AOI 8 beginning with the deepest units to the shallowest units.

Wissahickon Formation – Bedrock beneath the refinery and AOI 8 is identified as the Wissahickon Schist. This formation is a metamorphosed greenish-gray micaceous schist and quartzite. The competent bedrock of the Wissahickon Formation is overlain by weathered bedrock consisting of micaceous clay, which becomes increasingly sandy as the degree of weathering lessens and competent bedrock is encountered. Based on deep monitoring well and soil borings completed in AOI 8, the Wissahickon Schist ranges between approximately 40 feet beneath the ground surface in the northern portion of AOI 8 to approximately 70 feet beneath the ground surface in the southern portion. This range in bedrock depth is illustrated in Figure 5c.

Lower Sand Unit of the PRM – Throughout the majority of the refinery, the Wissahickon Formation is overlain by the Lower Sand, which is the lowest member of the Potomac-Raritan Magothy (PRM) Aquifer System. As shown in Figures 5a through 5c, the Lower Sand overlies bedrock in the eastern and central portions of AOI 8, but is absent in the northwestern and western portions where it has been eroded and replaced with alluvium.

The Lower Sand beneath AOI 8 is a green, brown, orange and/or red, fine gravel and course sand that grades upward into medium-to-fine sands and contains layers of silts and clay. The Lower/Middle Clay overlies the Lower Sand in the central and eastern portions of AOI 8 as shown in Figures 5a and 5b. As shown in Figures 5a through 5c, in the western and northwestern portions AOI 8, the Lower Sand is overlain by either alluvium or Trenton Gravel and the Lower/Middle Clay is absent. Where present at AOI 8, the Lower Sand ranges in thickness between 7 to 63 feet.

Fourteen deep (Lower Sand) groundwater monitoring wells existed in AOI 8 when the AOI 8 Work Plan was prepared. These monitoring wells included N-13, N-19, N-21, N-27, N-30, N-38D, N-4, N-43, N-46D, N-50D, N-69, N-79, N-83, and N-9. Using the geologic information gathered in AOI 8 as part of the characterization activities, the classification of the 14 monitoring wells were re-evaluated considering known geology and monitoring well construction. Based on this evaluation, three of these monitoring wells (N-69, N-79 and N-83) are not screened in the Lower Sand and therefore have been re-classified as intermediate monitoring wells.

Middle/Lower Clay – The Middle/Lower Clay, where present in beneath the refinery is characterized by very low permeability reddish-brown, brown or gray clays and sandy clays. Based on recent geologic data collected in AOI 8, the Middle/Lower Clay is present beneath AOI 8 as a wedge which thickens towards the west and the Schuylkill River. As shown in Figure 5a, the clay ranges in thickness from approximately 10 feet on the east side of AOI 8 to approximately 38 feet in the central portion of AOI 8.

Trenton Gravel – Throughout most of the refinery, the Trenton Gravel typically overlies the Middle/Lower Clay and Lower Sand with thicknesses up to 80 feet and a typical thickness of 40 feet. The Trenton Gravel is of Pleistocene Age (Ice Age; less than 2 million years) and is a very heterogeneous unit comprised of a predominant brown to gray sand, gravel and minor amounts of clay (Owens and Minard, 1979). As shown in Figures 5a through 5c, Trenton Gravel is present in the northern, central and eastern portions of AOI 8 and is absent in the western portion of AOI 8 where it has been eroded and replaced with alluvium.

Recent Fill/Alluvium - The alluvium deposits in AOI 8 generally consist of dark gray organic clayey mud or silt and fine sand. As shown in Figures 5a through 5c, alluvium deposits exist in the western and central portions of AOI 8 and to a lesser extent in the northern portion. No alluvium materials are located in the eastern portion of AOI 8. As shown in Figures 5a and 5c, the alluvium thickens in the western portion of AOI 8 where the Pleistocene age deposits have been eroded and replaced. As shown in Figures 5a through 5c, the alluvium deposits range in thickness between 2 and 60 feet in AOI 8.

Fill type varies across AOI 8 and includes various sands and gravels, brick and wood fragments, and cinder ash. Fill overlies native geologic deposits throughout AOI 8 and ranges between 2 and 15 feet in thickness.

In addition to the above descriptions, the following general observations can be made concerning the geology in AOI 8:

- Fill materials are present throughout AOI 8 generally ranging from 5 to 20 feet in thickness.
- In the western portion of AOI 8, the Pleistocene age formations have been eroded and replaced with alluvium. The alluvium extends to the central and northern portions of AOI 8, but is absent in the eastern portion. Where present the alluvium generally ranges in thickness from 5 to 60 feet.
- Trenton Gravel is present in the northern, central and eastern portions of AOI 8 but is absent in the western portion where it has been eroded and replaced with

alluvium. Where present the Trenton Gravel ranges in thickness from 5 to 30 feet.

- The Middle/Lower Clay is present beneath AOI 8 as a wedge that thickens towards the west and the Schuylkill River. The clay is absent between the central and western portions of AOI 8. Where present the clay ranges in thickness from 10 to 20 feet.
- The Lower Sand overlies bedrock in the eastern and central portions of AOI 8, but is absent in the northwestern and western portions of AOI 8. Where present the Lower Sand ranges in thickness from 2 to 60 feet.
- In the western and northern portions of AOI 8, the middle clay is absent, and the alluvium is in direct contact with Trenton Gravel, Lower/Middle Clay, Lower Sand and/or bedrock.
- The depth to bedrock beneath AOI 8 increases towards the south. Depth to bedrock in the northern portion of AOI 8 is generally encountered at 40 ft bgs and along the southern portion of AOI 8 is located at 75 ft bgs.

2.3 Hydrogeology

2.3.1 Shallow/Intermediate Groundwater Occurrence and Flow

Shallow groundwater at the refinery refers to unconfined groundwater that occurs in either the fill or alluvium (or both). Intermediate groundwater at the refinery refers to unconfined groundwater that occurs in Trenton Gravel. Groundwater gauging data collected by Stantec in May 2011 was used to generate a groundwater flow figure for the shallow/intermediate zone in AOI 8 (Figure 6). The groundwater elevation data from this gauging event is provided in Table 3. Monitoring well construction details for these monitoring wells are provided in Table 2 and boring/well construction logs for the newly installed monitoring wells are provided in Appendix C of this report. Historic boring/well logs for monitoring wells installed prior to the site characterization activities are provided in Appendix D of the CCR. Based on the groundwater elevations as shown in Figure 6, the following observations can be made.

- Groundwater in the shallow/intermediate zone of AOI 8 occurs at depths between 1 and 37 feet below the ground surface under unconfined conditions.

- A groundwater flow divide, trending northwest to southeast, is present in the central portion of AOI 8. This divide generally corresponds with the eastern extent of the alluvium materials deposited following the erosion and removal of the Pleistocene age deposits. Where the Pleistocene age deposits have been eroded, the alluvium is in direct contact with the Trenton Gravel, Lower/Middle Clay, and/or the Lower Sand. Groundwater on the east side of the divide flows to the northeast. Groundwater on the west side of the divide flows to the southwest.
- The hydraulic gradient in the western portion of AOI 8 is relatively flat with some depressions and mounds at isolated locations.
- Along the western boundary of AOI 8, flow is more pronounced towards the bulkheads and Schuylkill River.
- The hydraulic gradient in the eastern and southern portions of AOI 8 is relatively flat with some depressions and mounds at isolated locations.

2.3.2 Deep Groundwater Occurrence and Flow

Eleven deep (Lower Sand) monitoring wells are located in AOI 8 which include N-4, N-9, N-13, N-19, N-21, N-27, N-30, N-38D, N-44D, N-46D and N-50D. Well construction details for these monitoring wells are provided in Table 2 and the available logs for these monitoring wells are provided in the CCR.

Groundwater gauging data collected by Stantec in May 2011 was used to generate groundwater flow figures for the deep groundwater zone in AOI 8 (Figure 7). The groundwater elevation data from this gauging event are provided in Table 3. Based on the groundwater elevations as shown in Figure 7, the following observations can be made:

- A groundwater flow divide, trending northwest to southeast, is present in the central portion of AOI 8. This divide generally corresponds with the eastern extent of the alluvium materials deposited following the erosion and removal of the Pleistocene age deposits. Where the Pleistocene age deposits have been eroded, the alluvium is in direct contact with the Trenton Gravel, Lower/Middle Clay, and/or the Lower Sand. Groundwater on the east side of the divide flows to the east and southeast. Groundwater on the west side of the divide flows to the southwest.

- A downward vertical flow gradient exists between the shallow/intermediate and deep zone as indicated by the groundwater elevations in the following monitoring well pairs: N-3/N-4, N-12/N-13, N-8/N-9, N-18/N-19, N-20/N-21, N-29/N-30, N-38/N-38D, N-43/N-44D, N-47/N-46D and N-51/N-50D. This is consistent with vertical gradients elsewhere in the refinery.

No aquifer testing was performed in AOI 8 as part of the 2008 site characterization activities since sufficient data was available from former aquifer tests (pumping and slug tests) performed in AOI 8 by others (GES in 1993 and 1994). Aquifer testing, consisting of 40 and 48-hour constant rate pump tests were performed on two monitoring wells (N-76 and N-80) in AOI 8 by GES in December 1993. Slug tests were completed in August 1994 on monitoring wells N-29, N-32, N-81 and N-82. Based on these tests and other site specific data obtained from the CCR, for the fate and transport modeling a hydraulic conductivity of 24 ft/day was used for monitoring wells screened in the Trenton Gravel and a hydraulic conductivity of 4.64 ft/day was used for monitoring wells screened in the alluvium. A hydraulic conductivity of 135 ft/day was used for monitoring wells screened in the Lower Sand which was obtained from the USGS Water-Supply Paper 2346.

2.4 Surface Water

No surface water features are located in AOI 8. The nearest surface water body to AOI 8 is the Schuylkill River which borders the western boundary. Sheet pile and wooden bulkheads exist along the Schuylkill River as shown in Figure 2. The bulkhead extend along the Schuylkill River from the storm water separator south towards, and including, the active asphalt loading dock in the southwestern portion of AOI 8. The wooden portion of the bulkhead was constructed in the early 1930s and begins south of the AOI 8 storm water separator and extends approximately 2,460 feet downstream. In 1957, upgrades were completed to approximately 100 linear feet of the timber bulkhead that included steel sheet piles and partial replacement of timber spur piles with steel pipe piles. More recently, tie rods have also been installed in this area. The southern

940 feet of the bulkhead is of newer, steel sheet piling construction. Shallow/intermediate groundwater interaction with surface water is limited by the bulk head and sheet pile wall.

2.5 Jackson Street Sewer

To address question No. 2 of the PADEPs technical response letter (Appendix D), the following response was prepared to provide additional information on the Jackson Street Sewer. The Jackson Street sewer is a combined storm and sanitary sewer traversing the North Yard in an east-west direction. The sewer was constructed of brick between 1903 and 1917 and is 6.5 feet in diameter where it enters the refinery, on the eastern border near 29th Street and the Schuylkill Expressway. The sewer continues west across Sunoco property for 4,180 ft. at a grade of approximately 0.0028 ft. per ft. and increases in diameter to 7.5 ft. at its terminus, the Jackson Street Sewer Outfall on the Schuylkill River (GES 1993). Section 5.0 and 6.0 below provides an evaluation of the sewer as a transport mechanism for contaminants.

In response to questions No. 5 and 6 of the PADEPs technical response letter (Appendix D), a further evaluation of the sewer as a preferential migration pathway for light non-aqueous phase liquid (LNAPL) and vapor, was performed by Sunoco in 2009. As part of this evaluation, a review of historic investigations (1993 through 2009) was completed. A summary of the historic sewer investigations is presented below:

- In 1993 and 1995, investigations performed by GES and Sunoco determined the following:
  - Lithology surrounding the sewer consisted of poorly graded sand and gravel with lenses of silts and clays;
  - Construction of the sewer is brick;
  - The entire length of sewer intercepts alluvial groundwater;
  - Hydraulic conductivity values of the fill and alluvium ranged from 9.37x10-5 cm/sec to 1.51x10-4 cm/sec;
  - Transmissivity values of 1.49 cm2/sec suggested alluvial groundwater flow is semi-restricted;
  - Storativity value of 2.8x10-3 suggested limited water available for pumping; and

  - The highly variable grain size and finer grained; clay and silt lenses may limit the transmissivity and storativity of the unconfined aquifer.
- In 2002 and 2003, investigations performed by Aquaterra and Sunoco determined the following:
  - LNAPL existed in the subsurface proximal to the Jackson Street Sewer;
  - A groundwater remediation system controls the separate phase hydrocarbons plumes proximal to the Jackson Street Sewer;
  - Oil was present in the North Yard facility sewer system;
  - Sunoco improved operating procedures with regards to sewer system and completed sewer cleaning projects decreasing the presence of oil in the sewer; and
  - Improved operation of the Klondike separator and a higher degree of vigilance in the North Yard mitigated the discharge of oil to the Jackson Street Sewer Outfall.
- From December 2002 through September 2004, PADEP performed inspections in residential neighborhoods to the east of the site boundary. Petroleum odors were reported and PID readings ranged from 0.0 to 239 ppm.
- In February of 2003, PADEP and Philadelphia Water Department (PWD) inspected the interior of the sewer and determined the overall structural condition of the sewer was good. The PADEP and PWD observed evidence of hydrocarbons in the sewer using ultraviolet (UV) light. Increased amounts of hydrocarbons were observed towards the western portion of the sewer closer to the outfall structure.
- In March of 2003, Sunoco and Aquaterra mapped the inside of the sewer and mapped locations of hydrocarbon seep areas by use of ultra violet (UV) light and visual observations. Sunoco and Aquaterra also identified locations of other pipes tying into the sewer.
- In June and September of 2003, Sunoco performed outfall modifications, including the construction of an underflow weir, rerouting the discharge pipe from Klondike separator, automated the skimmer, and installed the water curtain.

- In September 2005, PADEP inspections reported no odors or PID readings present in nearby residential neighborhoods to the east of the site boundary.
- In 2005, Sunoco blanked off a pipe located at the western end of the sewer reducing amount of oil observed at outfall.
- In December of 2008, Sunoco and Stantec investigations reported no PID readings east of the water curtain.

In June 2009, Sunoco and Aquaterra collected 24-hour TO-15 summa air gas samples east and west of the water curtain alongside and inside of sewer (Figure 3). The air gas sampling was performed to evaluate possible vapor migration off-site in the residential neighborhood. The air gas sample results were screened against the PADEP residential indoor air screening criteria. The analytical results of the air gas samples indicated there were no benzene detections east of the water curtain or off-site in the sewer near residential neighborhoods. Chloroform was above its screening criteria west of water curtain (Manhole No. 1) and off-site in sewer (Manhole No. 6). Concentrations of COCs were below criteria in the background ambient air sample. Methane was detected in Manhole No. 3 west of the water curtain and in Manhole No.6 located in the residential neighborhood.

3.0 SITE CHARACTERIZATION ACTIVITIES

The following sections summarize the site characterization activities that were completed in AOI 8 in support of this report. Site characterization activities were performed between May and August 2008, by Aquaterra Technologies, Inc. (Aquaterra) and Langan in coordination with Sunoco. These activities were executed in accordance with the AOI 8 Work Plan for Site Characterization which is included as Appendix L of this report. Additional site characterization activities were performed in 2009 to address PADEP's comments in the technical response letter for AOI 8 dated November 14, 2008 (Appendix D).

3.1 Shallow Soil Borings and Sampling at Non-RCRA SWMU Areas

A total of 66 soil samples were collected for analysis of site COCs from areas within AOI 8 that are outside SWMU 2. The locations of all soil and monitoring well borings are shown on Figures 3 and 8 and the boring logs are provided in Appendix C. Soil samples were collected utilizing split-spoon sampling techniques. Soil borings were advanced to a maximum depth of two feet below grade at each unpaved location in accordance with the AOI 8 Work Plan.

Soil samples from the soil borings were submitted to Lancaster Laboratories, Inc. (LLI) of Lancaster, Pennsylvania for analysis of site COCs. A summary of the soil analytical results screened against the PADEP non-residential soil MSCs is provided as Table 4 and the results are discussed in Section 4.1. The laboratory analytical reports are provided as Appendix E.

3.2 Shallow Soil Borings and Sampling at SWMU 2

The 1991 RFI identified one SWMU in AOI 8 that required further characterization. This SWMU was identified as SWMU 2 (Storage Leaded Tank Bottoms Sludge Weathering Pad). SWMU 2 was characterized during the 2008 site characterization efforts following the investigative approach outlined in Section 1.2.2 of the AOI 8 Work Plan and summarized below:

- If materials were encountered within the leaded tank bottom areas matching the physical description of the leaded tank bottoms, then Sunoco collected samples for lead.
- If the lead results were above 450 parts per million (ppm) (PADEP's non-residential soil MSC for lead) then samples were analyzed for lead via Toxicity Characteristic Leaching Procedure (TCLP), EPA Test Method 1311.
- Delineated areas that had soils that physically resemble leaded tank bottoms, had lead concentrations greater than 450 ppm and failed the TCLP test for lead would retain the leaded tank bottom designation. If no soils were encountered that meet all three of the above mentioned criteria, then the area would no longer be classified as a leaded tank bottom area.

A detailed description of SWMU 2 and a summary of previous investigation work completed at SWMU 2 are provided in Section 1.2.1 of the AOI 8 Work Plan. To supplement data previously collected during the RCRA RFI, a total of six borings (BH-08-05, BH-08-06, BH-08-19, BH-08-20, BH-08-36, and BH-08-37) were completed in SWMU 2. The locations of these borings are shown on Figures 3 and 9 and the boring logs are provided in Appendix C. Soil samples were collected utilizing split-spoon sampling techniques. Soil borings were advanced to a maximum depth of eight feet below grade at each location in accordance with the AOI 8 Work Plan. At boring locations BH-08-36 and BH-08-37, the existing sub grade concrete slab was mechanically broken up with a backhoe to advance the soil borings. Locations BH-08-19 and BH-08-20 were located on asphalt which was also removed with a backhoe. No concrete slab was encountered at these two locations. The soils were evaluated to determine if leaded tank bottom materials were present.

Soil samples requiring analysis were submitted to LLI for analysis of lead concentrations. A summary of the soil analytical results is provided as Table 5 and the results are discussed in Section 4.2 below. The laboratory analytical reports are provided as Appendix E.

3.3 Installation of Groundwater Monitoring Wells

Monitoring well installation activities were performed between June and July 2008 by Parrat Wolff, Inc. (PWI) of East Syracuse, New York under direct supervision of Aquaterra and Langan, and in coordination with Sunoco. There were no new wells installed during the additional 2009 site characterization activities. The locations of all monitoring wells installed in 2008 are shown on Figure 3. Monitoring wells were installed to monitor the water table aquifers beneath AOI 8. No deep monitoring wells were installed since adequate characterization data exists from the three existing deep monitoring wells in AOI 8. The monitoring well installation activities are discussed in the following sections.

3.3.1 Fill/Alluvium (Shallow) and Trenton Gravel (Intermediate) Groundwater Monitoring Wells

PWI installed 39 shallow and intermediate monitoring wells which included N-100, N-101, N-102, N-103, N-104, N-105, N-106, N-107, N-108, N-109, N-110, N-111, N-112, N-113, N-114, N-115, N-116, N-117, N-118, N-119, N-120, N-121, N-122, N-123, N-124, N-125, N-126, N-127, N-128, N-129, N-130, N-131, N-132, N-133, N-134, N-135, N-136, N-98, N-99. Monitoring wells were installed and constructed under the direct supervision of Aquaterra and Langan in accordance with the AOI 8 Work Plan. Locations of these monitoring wells are shown on Figure 3. Monitoring well borings were advanced utilizing hollow stem augers and split spoon samplers to record lithology. Locations of these monitoring wells are shown on Figures 3. Boring logs and monitoring well construction details and lithology are provided in Appendix C. Monitoring wells were constructed with a flush mount manhole cover or with a stickup steel casing for protection. Following construction, the monitoring wells were developed in accordance with the AOI 8 Work Plan. Well construction details are provided in Table 2.

3.3.2 Lower Sand (Deep) Groundwater Monitoring Wells

Eleven deep (Lower Sand) groundwater monitoring wells exist in AOI 8; these monitoring wells included: N-4, N-9, N-13, N-19, N-21, N-27, N-30, N-38D, N-44D, N-46D, and 50D. No additional deep groundwater monitoring wells were installed in AOI 8 as part of the site characterization activities. Four deep soil borings were completed to a maximum depth of 103 feet for further geological characterization of AOI 8. The locations of the deep monitoring wells and deep soil borings are shown on Figure 3. Monitoring well construction details are provided in Table 2 and soil boring/well construction logs are provided in Appendix C. Geologic information obtained from the deep soil borings completed in AOI 8 was used to prepare geologic cross sections provided as Figures 5a through 5c.

3.4 Groundwater Monitoring

In May 2011, Stantec performed monitoring well gauging activities from all accessible monitoring points in AOI 8. Monitoring points were gauged for depth-to-water, and if applicable, depth-to-product in accordance with the AOI 8 Work Plan. The monitoring point gauging readings are summarized in Table 3.

The groundwater monitoring data from Table 3 was used to generate a shallow/intermediate groundwater elevation contours provided as Figure 6. Groundwater gauging data from the deep (Lower Sand) monitoring wells in Table 3 was used to generate a groundwater contour figure for the deep (Lower Sand) zone in AOI 8 (Figure 7).

3.5 Groundwater Sampling

Aquaterra performed a round of groundwater sampling from accessible monitoring wells in AOI 8 in July 2008. A total of 111 groundwater samples were collected during this groundwater sampling event. Groundwater sampling activities were completed in accordance with the AOI 8 Work Plan. The monitoring well sampling summary data sheets are provided as Appendix F.

Following monitoring well purging activities, groundwater samples were collected by lowering a disposable bailer slowly into the monitoring well to minimize excess agitation. The bailer was filled with water from the top of the water table and retrieved. Samples were then collected in laboratory-prepared bottleware and immediately placed on ice. Samples were submitted to LLI for analysis of site COCs. Once the sample was collected, the bailer, bailer cord, and nitrile gloves used to obtain the sample were discarded. Sample date, time, number, and site name were recorded on the chain-of-custody and in field books. For groundwater samples analyzed for lead, LLI filtered the samples to analyze for dissolved concentrations.

The groundwater analytical results for shallow monitoring wells were screened against the PADEP non-residential groundwater MSCs and are presented in Table 6. The groundwater analytical results for the deep monitoring wells are presented in Table 7. The laboratory analytical reports are included as Appendix E.

3.6 LNAPL Sampling

LNAPL samples for select monitoring wells in AOI 8 were previously characterized as described in the CCR. As part of the 2008 site characterization activities, Aquaterra collected LNAPL samples from a total of eleven existing monitoring wells (N-42, N-47, N-51, N-75, N-76, N-82, N-91, N-503, RW-202, RW-300 and RW-305) in AOI 8 to further characterize LNAPL in AOI 8. Eight LNAPL samples were collected from newly installed monitoring wells (N-107, N-113, N-116, N-125, N-127, N-129, N-130, and N-135). LNAPL samples were collected using a direct sampling method in accordance with the AOI 8 Work Plan. LNAPL samples were packaged in certified hazardous material shipping boxes and shipped to Torkelson Laboratories (Torkelson) of Tulsa, Oklahoma for LNAPL characterization. LNAPL characterization data included product types, density, proportions of product, degree of weathering, and similarities to other LNAPL samples collected at the refinery.

Appendix G summarizes the LNAPL characterization results for samples collected in AOI 8 as well as previous results from the CCR.

3.7 Surveying Activities

Following completion of monitoring well installation and soil boring activities, the newly installed monitoring wells and soil boring locations were surveyed by Langan to establish the location and elevation of the inner and outer casing and ground surface at each point. Well elevations were determined to the nearest 0.01 foot relative to mean sea level. Survey activities were performed by a Pennsylvania-licensed surveyor and tied to the NAVD 88 datum. The new survey data for the monitoring wells is presented in Table 2. This new survey data was used to update the Geographic Information System (GIS) and site wide database for the refinery.

3.8 Vapor Intrusion Assessment Activities

<u>Philadelphia Firehouse Building</u>

Based on the presence of LNAPL in monitoring well MW-7 which is located approximately 150 feet southeast of the Philadelphia Fire Department building, and since there are no monitoring points between MW-7 and the fire department building, further evaluation of the potential vapor intrusion into indoor air pathway for this building was completed in 2009. A total of four soil gas monitoring points (SG-1 through SG-4) were installed around the perimeter of the fire department building in April 2009 by Aquaterra. These soil gas monitoring points were installed adjacent to the northeast and southeast exterior walls of the building. The soil gas monitoring points were left as permanent monitoring points for use in future sampling events. The soil gas monitoring points were sampled on April 23, 2009 by Aquaterra. In addition to the soil gas point samples, on June 5, 2009, two indoor air gas samples (Firehouse Ambient and Firehouse Indoor Air) were collected by Aquaterra. The soil gas sample locations are shown on Figure 3 and the field notes and analytical summary tables are presented in Appendix H. The soil gas sampling activities were completed in accordance with the procedures provided in the AOI 8 Work Plan. The soil gas and indoor air samples were analyzed via EPA Method TO-15 by LCI.

<u>Jackson Street Sewer Vapor Assessment</u>

In response to question No. 5 of the PADEPs technical response letter (Appendix D), a total of four air samples were collected around and in the Jackson Street Sewer on June 5, 2009. Sunoco and Aquaterra collected 24-hour TO-15 summa air samples east and west of the water curtain alongside and inside of sewer. The locations of these samples are shown in Figure 3. The air samples were analyzed via EPA Method TO-15 by LCI. The following is description of each air sample location:

- One ambient background air sample (Jackson Ambient) was collected east of the water curtain;
- Manhole No.1 collected on the east side of the water curtain;
- Manhole No.2 collected on the west side of the water curtain; and
- Manhole No. 6 collected offsite on the east side of Route 76 in the vicinity of South 29th Street in a residential neighborhood.

The result of this sampling is summarized in Section 5.5.

4.0 QUALITY ASSURANCE/QUALITY CONTROL

The following sections outline the field and laboratory quality assurance/quality control measures that were incorporated into the site characterization activities. All groundwater gauging and sampling activities were completed in accordance with the field sampling procedures presented in the AOI 8 Work Plan. The complete laboratory analytical data packages for the soil and groundwater sampling events are included in Appendix E.

4.1 Equipment Decontamination

All sampling equipment was decontaminated in accordance with the field sampling procedures to prevent cross-contamination. Prior to sampling, the equipment was decontaminated with successive rinses of detergent and potable water and distilled deionized water. All down-hole equipment used in monitoring well purging, such as submersible pumps, was cleaned with an external non-phosphate detergent wash and tap water rinse. This cleaning process was followed by a flush of potable water.

4.2 Equipment Calibration

Prior to each use, the Horiba instrument was calibrated by measuring the parameters using manufacturer-provided buffer solutions, deionized water and zero oxygen solution.

4.3 Sample Preservation

Samples were preserved, where necessary, with the addition of chemical preservatives, and by cooling the samples at 4°C before and during shipment to the laboratory. Chemical additives necessary for sample preservation were added to the sample containers by the analytical laboratory prior to releasing them to sampling personnel.

4.4 Laboratory Quality Assurance/Quality Control

For the purposes of this investigation, sample results were summarized in thirty one sample delivery groups, provided by LLI, and are evaluated in the sections above for usability. Copies of the laboratory reports are provided in Appendix E for your reference.

The laboratory performed quality assurance and quality control (QA/QC) analyses, including laboratory control spikes and laboratory control spike duplicates, matrix spikes and matrix spike duplicates, surrogate spikes, method blanks and QA/QC checks such as GC/MS instrument tuning and mass calibration, as appropriate. Laboratory QA/QC summaries were completed by the laboratory and provided in each data package, attached. The analytical data, data qualifiers, and QC results provided in these reports were evaluated to determine the confidence with which this groundwater, soil and air data could be used in the decision-making process.

Data quality indicators (DQIs) are qualitative and quantitative measures of data quality "attributes," which are descriptors used to express various properties of analytical data. Thus, DQIs are the various measures of the individual data characteristics that collectively comprise the general, all-encompassing term "data quality." Quality attributes used to assess the data usability include:

- Method selectivity/specificity
- Accuracy (bias)
- Precision
- Representativeness
- Comparability
- Completeness

Based on evaluation of these indicators the groundwater, soil and air data collected during this investigation are considered usable for characterizing the site, identifying compounds of concern, and delineating potential impacts, with the exceptions described below.

For compounds analyzed in soil (with exception of ethylene dibromide) greater than 95% percent of the data is considered usable. The remaining 5% is considered unusable because, due to matrix interference, the samples were diluted to the point that the laboratory reporting limits were elevated above the corresponding soil screening criteria (PADEP Soil MSCs) and no concentration was detected. Specifically, MTBE in samples N-109_1.0-2.0 and N-126_1.0-2.0; benzene in samples N-109_1.0-2.0, N-122_1.0-2.0, and N-126_1.0-2.0; and 1,2-dichloroethane in samples N-109_1.0-2.0, N-122_1.0-2.0, and N-126_1.0-2.0 are not considered usable for the purposes of characterization and delineation. Similarly, due to matrix interference, ethylene dibromide is also considered unusable in any sample because the laboratory reporting limits were elevated above the PADEP Soil MSC.

For compounds analyzed in groundwater (with exception of chrysene) greater than 92% percent of the data is considered usable. The remaining 8% is considered unusable because, due to matrix interference, the samples were diluted to the point that the laboratory reporting limits were elevated above the corresponding groundwater screening criteria (PADEP GW MSCs) and no concentration was detected. Specifically, 1,2-dichloroethane in samples N-23, N-34, N-35, N-58, N-61, N-119, N-133 and PZ-506; benzene in samples N-23, N-34, N-35, N-58, N-61 and PZ-506; and naphthalene in sample N-36. Similarly, due to matrix interference, chrysene is also considered unusable in any sample because the laboratory reporting limits were elevated above the PADEP groundwater MSC.

One hundred percent of the air data is considered usable, with select concentrations considered biased and therefore estimated.

Due to the number of samples collected and the high percentage of useable data, the data collected is sufficient for the completed Remedial Investigation activities. In addition, as detailed in Appendix E, few concentrations should be considered as biased because LCS/LCSD, MS/MSD and surrogate recoveries were beyond acceptable control limits. Reviews of the biased concentrations show that it is unlikely that any of the concentrations would have exceeded the standard had the bias not occurred.

4.5 Documentation

Chain-of-custody forms were maintained throughout the sampling program to document sample acquisition, possession and analysis. Chain-of-custody documentation accompanied all samples from the field to the laboratory. Each sample was assigned a unique number that was recorded on permanent field sheet.

5.0 SITE CHARACTERIZATION ANALYTICAL RESULTS

The following sections discuss the analytical results of the site characterization activities performed in AOI 8.

5.1 Soil Analytical Results at Non-SWMU Areas

A total of 66 soil samples were collected for analysis of site COCs from areas within AOI 8 that are outside SWMU 2. The results of the soil samples collected outside of SWMU 2 are provided in Table 4 and are summarized below. Soil samples were collected between the ground surface and two feet below the ground surface and no saturated soils were observed at these depths. The soil sample results were screened against the PADEP non-residential soil MSCs. Soil sample locations with results above their respective soil MSCs are shown in Figure 8. COCs detected in soil, above their respective non-residential soil MSCs included: benzene, naphthalene, benzo(a)pyrene and lead.

5.2 Soil Results at SWMU 2

The following approved procedures were followed in relation to potential leaded tank bottoms. Soil samples were collected for lead if materials were encountered within the leaded tank bottom sludge weathering pad area during site characterization activities matching the physical description of the leaded tank bottom materials. If the lead results exceeded 450 ppm (the PADEP non-residential MSC for lead), then the samples were analyzed for lead via TCLP, EPA Test Method 1311.

A total of six soil borings/samples (BH-08-05, BH-08-06, BH-08-19, BH-08-20, BH-08-36, and BH-08-37) were completed at SWMU 2. One sample location (BH-08-05) exhibited trace amounts of material with characteristics resembling the physical description of leaded tank bottoms and was submitted for lead analysis. The sample collected from boring BH-08-05 exhibited a lead concentration below the PADEP non-residential MSC (450 ppm) and was therefore not submitted for TCLP analysis. No evidence of leaded tank bottom materials was observed in the remaining five soil borings. The results of the sample analyses are summarized in Table 5, illustrated in Figure 9, and the logs for these borings are provided in Appendix C.

5.3 Groundwater Results

Shallow/Intermediate and Deep (Lower Sand) Monitoring Wells

The results of the groundwater samples collected from monitoring wells in the shallow/intermediate and deep groundwater zones are provided in Tables 6 and 7. The results were screened against the PADEP non-residential used aquifer (TDS<2,500) groundwater MSCs. Locations with concentrations above the groundwater MSCs are illustrated in Figure 10. A summary of the COC concentrations that were above their respective PADEP non-residential groundwater MSCs are presented below.

Shallow/Intermediate Monitoring Wells

- COCs detected in shallow/intermediate monitoring wells at concentrations above their respective non-residential groundwater MSCs included: benzene, pyrene, chrysene, phenanthrene, and naphthalene.
- Cumene, toluene, ethylbenzene, ethylene dibromide, xylenes, fluorene, MTBE, 1,2-dichoroethane and lead were not detected in AOI 8 groundwater at concentrations above their respective non-residential groundwater MSCs.

Deep (Lower Sand) Monitoring Wells

- Benzene was detected in three deep (Lower Sand) monitoring wells (N-9, N-21, N-44D) at concentrations slightly above its respective non-residential PADEP groundwater MSC.
- Toluene, MTBE, 1,2-dichoroethane, xylenes (total), cumene, ethylbenzene, ethylene dibromide, pyrene, phenanthrene, fluorene, naphthalene, and lead were

not detected in deep groundwater in AOI 8 at concentrations above their respective PADEP non-residential groundwater MSCs.

5.4 LNAPL Characterization Results

As a part of the site characterization activities for AOI 8, LNAPL samples were collected from 18 monitoring wells (N-42, N-47, N-51, N-75, N-76, N-82, N-91, N-503, RW-205, RW-300, RW-305, N-107, N-113, N-116, N-125, N-127, N-129, N-130, and N-135). This appendix also includes previous LNAPL characterization data for AOI 8 which was obtained as part of the CCR. As part of the CCR, LNAPL samples were collected from 11 monitoring wells (N-14, N-25, N-31, N-35, N-48, N-52, N-68, N-78, N-79, PZ-204, and PZ-502). The LNAPL samples collected from AOI 8 were submitted to Torkelson Geochemistry, Inc. (Torkelson) of Tulsa, Oklahoma for characterization. The extent of LNAPL, the LNAPL type, as well as the apparent thickness of LNAPL measured during the May 2011 gauging event is illustrated in Figure 11. The LNAPL product typing and characterization results are presented in Appendix G.

As part of the AOI 8 SCR/RIR, LNAPL modeling was performed using the American Petroleum Institute (API) Model. LNAPL modeling procedures, input parameters, and results are included as Appendix G. LNAPL was identified in 43 wells (N-14, N-23, N-25, N-31, N-42, N-45, N-47, N-48, N-49, N-503, N-504, N-51, N-52, N-54, N-68, N-75, N-76, N-79, N-81, N-82, N-91, PZ-204, PZ-502, RW-201, RW-203, RW-204, RW-205, RW-206, RW-300, RW-306, RW-502, N-107, N-112, N-113, N-115, N-116, N-125, N-127, N-128, N-129, N-130, N-135, and P-30) during the May 2011 groundwater gauging activities. LNAPL thicknesses ranged from sheen (0.01 feet) to 3.20 feet.

Based on the LNAPL characterization performed by Torkelson, the LNAPL types present in AOI 8 consist of four different types or mixtures of LNAPL including residual oil, lube oil, lube oil/middle distillate mixture, and middle distillate. All four LNAPL types have a high degree of weathering. The physical properties of these LNAPL types (drawn from literature sources), soil types (AOI 8 boring logs) and recent LNAPL thickness measurements (May 2011) were entered into the API Model to estimate LNAPL specific volume and seepage velocity. The input and output parameters of the updated API Model and seepage velocity calculations is presented in Appendix G.

The distribution of LNAPL, specific volume and seepage velocities derived from the May 2011 data are similar to what was reported in the CCR. Figures depicting the results of the LNAPL modeling are included in Appendix G. Based on the LNAPL types, LNAPL modeling results and recent groundwater gauging activities, LNAPL in these wells is stable and generally immobile.

5.5 Vapor Intrusion Assessment Results

The Philadelphia Fire Department building soil gas and Jackson Street Sewer air sample locations are presented on Figure 3. The vapor intrusion assessment field notes and analytical summary tables are provided in Appendix H. The analytical laboratory reports are presented in Appendix E. Sampling techniques were completed in accordance with the procedures of the AOI 8 Work Plan. Samples were collected via EPA Method TO-15 and analyzed by LCI.

The results of the sampling are summarized below:

<u>Philadelphia Fire Department Building</u>

- Benzene was detected above its respective PADEP indoor air screening criteria in three of the four soil gas sample locations.
- Benzene was not detected above the PADEP indoor air screening criteria in the two indoor air samples collected from inside the fire department building.
- 1,4-dichlorobenzene was detected above the PADEP indoor air screening criteria in one of the samples collected inside the building; however, the presence of this compound in indoor air is likely attributable to background conditions at the time the sampling was completed because concentrations of this compound were not detected in the soil gas samples.

<u>Jackson Street Sewer</u>

In June of 2009, Sunoco and Aquaterra collected 24-hour TO-15 summa air samples east and west of the water curtain as background samples and one sample inside of the sewer. Below is a summary of those results:

- Benzene was detected above the PADEP indoor air screening criteria on-site at Manhole No. 3 sample location.

- Benzene was not detected at concentrations above the PADEP indoor air screening criteria east of water curtain or off-site.
- Chloroform was detected above the PADEP indoor air screening criteria west of the water curtain (Manhole No. 1) and off-site in the sewer (Manhole No. 6). This compound is not attributed to site COCs.
- No exceedances of indoor air screening criteria in background ambient air sample.

With the exception of the above-mentioned compounds, all other TO-15 compounds were below their respective PADEP residential indoor air screening criteria. Methane was present in two of the samples collected inside the sewer (Manhole No. 3 and Manhole No. 6); however, there are no screening criteria for this COC. The analytical results indicated that indoor air exceedances were detected west of the water curtain, but not to the east, indicating that the water curtain is effectively controlling vapor migration from the sewer. Although methane was detected east of the water curtain, it is associated with a background source.

6.0 REMEDIAL SYSTEM EVALUATION AND UPDATE

6.1 PGW Border Total Fluids Recovery System

The PGW Total Fluids Recovery System is composed of recovery wells numbered RW-200 through RW-205 and an interceptor trench with a recovery sump (RW-206). The system was installed to help prevent off-site migration of LNAPL. The system recovery network consists of total fluids recovery utilizing electric submersible pumps equipped with individual timers to control the on and off cycle of each pump. Total fluids are extracted from recovery wells RW-201, RW-202, and RW-203. Total fluids produced by the 200 series pumps are routed to the North Yard 10,000-gallon holding tank where a flow meter measures incoming fluids produced by the three recovery wells. Groundwater is passed through the tank and routed to the Point Breeze Processing Area Wastewater Treatment Plant. Accumulated LNAPL is pumped out of the 10,000-gallon holding tank as needed by a vacuum truck. The recovered LNAPL is quantified while being vacuumed from the holding tank.

The PGW Total Fluids Recovery System was taken off-line during in March 2008 due to electrical issues associated with the system and maintenance on the 10,000-gallon holding tank and has remained off-line. Although the system shut down was initiated due to maintenance issues, this shutdown allowed time to evaluate the AOI 8 recovery systems. Based on an evaluation of this system and the dissolved phase concentration in the vicinity of the PGW border, re-initiation of this system is recommended and will be further described in the Clean Up Plan.

6.2 Jackson Street Sewer Total Fluids Recovery System

This section describes activities performed, and information gathered, to address Question No. 3 of the PADEPs technical response letter (Appendix D).

According to the 1995 Brown & Root, Inc. Ground Water Remediation Project Data Book Volumes 1 and 2, the original recovery network was to include a total of nine recovery wells. The original purpose of this system was to control the LNAPL plume in the center of the North Yard and prevent LNAPL migration to the Jackson Street Sewer and Schuylkill River. Installation occurred sometime prior to March 1995 and is reflected in the system "As Builts."

The recovery network originally included a total of nine recovery wells: RW-300 through 308. Total fluids produced from the recovery wells were routed to the North Yard 10,000-gallon holding tank where a flow meter recorded the combined total fluids produced from the recovery well network. Groundwater is passed through the tank and routed to the Point Breeze Processing Area Wastewater Treatment Plant. Accumulated LNAPL is pumped out of the 10,000-gallon holding tank by a vacuum truck quarterly. Since all three AOI-8 recovery systems are routed to the 10,000-gallon holding tank the actual volume of LNAPL recovered from each individual system was not able to be determined.

The Jackson Street Sewer Total Fluids Recovery System was taken offline during the first week in March 2008 due to maintenance issues and has remained offline. Although the system was shut down due to maintenance issues, this allowed time to evaluate the system's performance.

The Jackson Street combined sewer overflow ("CSO") outfall is checked once per shift at low tide and findings are recorded twice daily by Sunoco personnel to determine if a sheen or LNAPL are present. Flow through the sewer during a severe rain storm in August 2005 damaged the outfall structure beyond repair. The outfall structure has since been removed and the installation of a slide boom structure at the outfall was completed in May 2006. An absorbent boom was placed behind the slide boom in response to a slight sheen at the outfall in April 2007. Currently, there is no evidence of oil in the Jackson Street sewer and it outfalls to the river with no controls.

Recovery wells are gauged as part of the quarterly recovery system maintenance and monitoring program to ensure the system is operating as designed. Recovery wells RW-304 and RW-308 were taken off-line in August 1999. Recovery wells RW-303 and RW-305 through RW-308 were taken off-line in August 2004 due to the absence of measurable LNAPL (>0.01 feet). These recovery wells are monitored semi-annually and will be brought back on-line if measurable LNAPL returns.

To evaluate the historical performance of the total fluids recovery system, Langan had compiled data from quarterly reports and other historical documents from 1992 through December 2010. Recovery wells (RW-301 through RW-308) were included as part of the analysis, as well as eight surrounding monitoring wells (N-20, 22, 23, 24, 25, 26, 79, and 87). Trend charts were prepared to compare the corrected groundwater elevation and apparent LNAPL thickness over time. These trend charts are presented as Appendix I. Depicted on the graphs are the dates when the pumps were shut down. If the product thickness is shown to be zero on the graphs, this indicates that either a sheen was observed or there was no measurable LNAPL. If no data point is present on the graphs, then there was no sheen or measurable LNAPL observed. Included in Appendix I, are figures presented in chorological order (by date) that depict apparent LNAPL locations, thickness, and plumes over time. The data analysis, attached graphs and figures indicate a general decreasing trend in apparent LNAPL thickness in the recovery and nearby monitoring wells over time.

Due to lack of LNAPL in the vicinity of the system (Figures 3 and 11), Sunoco intends to keep the system offline. The Jackson Street Sewer outfall will continue to be monitored to confirm lack of LNAPL presence.

6.3 Jackson Street Sewer Water Curtain

Installation of a water curtain in the Jackson Street sewer was completed during the 4th quarter of 2003. The water curtain is designed to reduce hydrocarbon odors potentially migrating from the Jackson Street sewer to the surrounding areas. The water curtain apparatus is located in the first manhole west of the interceptor chamber along 26th Street and consists of a single centrally located nozzle that emits a radial spray pattern. Water is supplied to the water curtain apparatus from the North Yard fire water system. Heat trace equipment was installed along the water feed line allowing winter operation of the water curtain.

The current water curtain system monitoring includes vapor readings from the interceptor chamber and at the manhole of the water curtain. Historically, flowrate/totalizer readings were recorded but the totalizer has been removed due to continuous fouling. Although the clogged totalizer did not restrict flow, the fouling frequently caused inaccurate or no measurements and the totalizer was removed during the 4th Quarter of 2009.

Langan and Sunoco performed field sampling activities to evaluate the effectiveness of the water curtain system with respect to preventing off-site migration of vapors. The results of this evaluation are presented in Section 6.5 of this report.

6.4 North Yard Bulkhead/No. 3 Tank Farm Separator Total Fluids Recovery System

This section describes activities performed, and information gathered, to address Question No. 4 of the PADEPs technical response letter (Appendix D).

The North Yard Bulkhead Total Fluids Recovery System currently consists of a 3,400-feet long interceptor trench with two recovery sumps (RW-500 and RW-501). The No. 3 Tank Farm Separator Total Fluids Recovery System consists of one recovery system RW-502 located in the center of the capped closed separator. These systems addressed potential migration of LNAPL into the Schuylkill River. RW-500, RW-501 and RW-502 utilize electric submersible pumps and are controlled by a timer to recover total fluids. The total fluids from the three recovery wells were pumped to the North Yard 10,000-gallon holding tank where a flow meter measured incoming fluids pumped from the recovery wells. Groundwater passed through the tank and was routed to the Point Breeze Processing Area Wastewater Treatment Plant. Accumulated LNAPL is pumped out of the 10,000-gallon holding tank as needed by a vacuum truck.

Regarding the systems operation and success, Langan compiled system monitoring data from the quarterly reports and other historical documents from 1992 through December 31, 2010. Recovery wells (RW-500 through RW-502) were included along with eight surrounding monitoring wells (N-55, 57, 58, 59, 61, 64, 72, and 73D). Trend charts were prepared to compare the corrected groundwater elevation and apparent LNAPL thickness over time. These charts are provided in Appendix I. If the product thickness is shown to be zero on the graphs, this indicates that either a sheen was observed or there was no measurable LNAPL. If no data point is present on the graphs, then there was no sheen or measurable LNAPL observed. Included in Appendix I are figures presented in chorological order that depict apparent LNAPL locations, thickness, and plumes over time.

The remedial system evaluation indicated a general decreasing trend in apparent LNAPL thickness in the recovery and nearby monitoring wells overtime. In the 3rd quarter of 2010, the North Yard Bulkhead and No. 3 Tank Farm Separator Total Fluids Recovery Systems were taken offline due to lack of LNAPL in the vicinity of the system. Due to lack of LNAPL in the vicinity of the system, Sunoco intends to keep the system offline.

7.0 FATE AND TRANSPORT ANALYSIS

The following sections describe fate and transport modeling activities performed as part of AOI 8 site characterization.

7.1 Soil

No fate and transport modeling was completed for the soil analytical results since the soil-to-groundwater pathway is evaluated through groundwater data. Potential exposure pathways for AOI 8 are discussed in more detail in Sections 9.0 and 10.0 below.

7.2 Groundwater

Fate and transport calculations were completed for groundwater in AOI 8 to evaluate potential migration pathways/potential impacts to receptors.

Five COCs were detected in groundwater during the July 2008 groundwater sampling event at concentrations above their respective MSCs. These COCs are benzene, pyrene, chrysene, phenanthrene and naphthalene. Groundwater samples from 53 monitoring wells in AOI 8 exhibited COC detections above their respective used-aquifer, non-residential groundwater medium specific concentrations (MSCs) for one or more of the above mentioned COCs.

To address the potential future migration of these COCs, a fate and transport analysis was performed using three models developed by PADEP. The Quick Domenico Version 2 (QD) model and the SWLOAD model were used for fate and transport in groundwater. PENTOXSD was used when assessing potential impacts of groundwater on surface water from organic COCs. Site-specific data was used to complete the fate and transport calculations, when available. A detailed summary of the procedures and calculations of the modeling procedures are presented in Appendix J. The approach and results of the modeling are discussed below.

<u>Screening and Approach to Fate and Transport Analysis</u>

Based on groundwater flow directions derived from May 2011 groundwater elevations (Figures 6 and 7) and the locations of potential off-site receptors AOI 8 was divided into three drainage areas for fate and transport analysis. Locations of each of these drainage areas are show on Figure J.1 of Appendix J.

- Drainage Area 1 is located in the eastern portion of AOI 8. The western boundary of Drainage Area 1 was defined as the groundwater divide where groundwater flow is generally east towards the AOI 8 property line. QD modeling was used to address potential off-site impacts along the AOI 8 northeast boundary.
- Drainage Area 2 consists of the central and western portions of AOI 8 where groundwater flow is generally towards the Schuylkill River. To address potential off-site impacts along the Schuylkill River the QD model was used first; then the SWLOAD model; then, as need, PENTOXSD.

- Drainage Area 3 was not defined hydraulically like Drainage Areas 1 and 2 but was used to delineate where active remediation will be conducted. Drainage Area 3 is located along the southern AOI 8 property boundary.

Groundwater concentrations at AOI 8 are assumed to be at or near steady-state for this analysis. A detailed description of the fate and transport modeling is presented below based on the three drainage areas and the July 2008 groundwater analytical results.

Drainage Area 1 Wells

1. Wells with exceedences of benzene, chrysene, pyrene and phenanthrene that are located hydraulically up-gradient of wells with non-exceedences of COCs and had stable groundwater trends did not undergo analysis by QD. The Drainage Area 1 wells that fall into this category include: N-11, N-106, N-12, N-102, N-103, N-104, N-20, N-21, and N-97. These wells are located up gradient of northeast property boundary wells N-3, N-4, N-8, N-16, N-17, N-19, N-84, N-85, N-28 and N-134 which do not contain COC concentrations above their respective MSCs.
2. N-9, N-12 and N-101, have exceedences of one or more COCs (benzene, pyrene, chrysene and phenanthrene) and are located up gradient of the northeast property boundary where no down gradient monitoring wells exist. To assess potential migration beyond the northeast property boundary for N-12 and N-101, a QD model was constructed. Fate and transport for benzene at deep well N-9 (screened in Lower Sand) was addressed in the AOI 11 report, where it was noted that benzene concentrations at N-9 exhibited decreasing trends to non-detect. Deep monitoring wells down gradient of N-9 also exhibited non-detects and was therefore not modeled.
3. As a check on the results of Drainage Area 1 fate and transport evaluation, a QD simulation was created for N-106 which had the highest benzene concentration in Drainage Area 1 (410 ug/l). Benzene is the most mobile of the COCs present therefore its ability to attenuate before it reaches N-98, near the northeast property line and where benzene was not detected, was further evaluated and the modeled results supported the observed groundwater concentrations.
4. At all sampled monitoring well locations in Drainage Area 1, laboratory RLs for chrysene were higher than the groundwater MSC of 1.9 ug/l. To ensure that the

potential for chrysene to impact off-site groundwater was evaluated, an additional QD simulation was constructed using site conditions found at N-8 (located about 25 feet from the property boundary) using the most elevated, site-wide chrysene RL of 120 ug/l as the starting concentration.

<u>Drainage Area 2 Wells</u>

1. Benzene detections above the groundwater MSC in Drainage Area 2 wells could be found in two general areas. The first area was at the center of AOI 8 (which includes RW-301, RW-303, RW-304, RW-305, RW-307, RW-308, N-108, N-121, N-118, N-119, N-123, N-44D and PZ-300) and second area was near the Schuylkill River on the west side of Drainage Area 2 (which includes N-59, N-61, N-136, N-133, PZ-503, PZ-504, PZ-505 and RW-500). Fate and transport of benzene groundwater impacts originating in the center of AOI 8 were not modeled because benzene impacts were not detected hydraulically downgradient of this area. Four monitoring well locations (N-23, N-34, N-35 and N-36) at the center of AOI 8 had benzene RLs above the benzene groundwater MSC and were reported not detected. Well locations down-gradient of these four monitoring wells had no benzene detections above the groundwater MCS and therefore were not further evaluated.

   Benzene groundwater impacts in wells located along the Schuylkill River were further evaluated with QD. Based on the July 2008 groundwater data, eight wells along the wooden bulkhead had detected benzene concentrations ranging from 13 ug/l to 10,000 ug/l. These eight wells are located along a 1,500 feet stretch of the Schuylkill River within approximately 250 feet from the bulkhead. A benzene isoconcentration map was constructed using the July 2008 data as shown in Figure J.3. The highest benzene concentration detected along the bulkhead was found near monitoring wells N-133 (10,000 ug/L) and N-61 (8,700 ug/L). Benzene concentrations decreased to the north and south of N-133 and N-61. To assess the entire 1,500 feet stretch of benzene impacts, the impacted area was broken into four zones to better define the variation in benzene concentration within the plume. For each zone a QD and SWLOAD model was constructed. If the SWLOAD results still exceeded the benzene surface water quality criteria (SWQC), PENTOXSD was used to derive a site-specific benzene wasteload allocation to re-screen the SWLOAD results.

N-58 and PZ-506 located along the Schuylkill River had elevated benzene RLs but was listed as not detected. QD and SWLOAD simulations for benzene at N-58 and PZ-506 were constructed using the benzene RLs as the starting concentration.

2. Naphthalene concentrations were detected above the groundwater MSC at three Drainage Area 2 wells (N-23, N119, and N-123) and evaluated using QD. The naphthalene RL at N-36 was greater than its MSC but listed as a not detect. No modeling was performed for naphthalene at this location because it was located in the center of AOI 8 and naphthalene impacts were not detected down-gradient of this monitoring well.

3. Phenanthrene concentrations were detected above the groundwater MSC at two monitoring wells (N-112 and N-128) in Drainage Area 2. Wells located down gradient of N-112 and N-128 were not impacted by phenanthrene, therefore, no fate and transport modeling was performed.

4. Chrysene detections above the groundwater MSC are ubiquitous in AOI 8. Due to the low affinity for transport (strong tendency to sorb to aquifer materials) and stable groundwater trends in interior wells potential impacts of chrysene on surface water were assessed at locations along the Schuylkill River only. The wells included in this evaluation included N-111, N-60, PZ-503, PZ-505, PZ-506, PZ-507 and RW-200.

   Chrysene impacts in Drainage Area 2 wells located along the Schuylkill River were first screened against the chrysene SWQC found in the PA Code Chapter 93.8c. Neither chronic nor acute SWQC for chrysene have been derived for the PA Code. Therefore additional screening was done with US EPA Lowest Observable Effect Level (LOELs) for acute exposure to chrysene in the marine environment of 300 ug/l. Screening results indicate that chrysene at present concentrations does not exceed the LOEL value along the bulkhead. Groundwater is impacted by chrysene near the Schuylkill River when compared to the human health SWQC of 0.0038 ug/l. Chrysene was assessed using QD and SWLOAD. If the SWLOAD results still exceeded the groundwater quality criteria, PENTOXSD was used to derive a site-specific wasteload allocation to re-screen the SWLOAD results.

Chrysene RLs at all sampled monitoring wells in Drainage Area 2 were higher than the chrysene groundwater MSC of 1.9 ug/l. To ensure chrysene will not impact off-site surface water, a simulation was constructed using site conditions found at PZ-504 (26 feet from the bulkhead) and the site-wide maximum chrysene RL of a 120 ug/l was used as the starting concentration. The result of this simulation was used to evaluate chrysene in Drainage Area 2 near the Schuylkill River.

5. Pyrene has a strong affinity to sorb to aquifer materials and a low affinity for transport. Therefore the assessment of pyrene for potential fate and transport was focused along the Schuylkill River.

   Based on the July 2008 groundwater data, pyrene was detected above its groundwater MSC of a 130 ug/l at two monitoring well locations (N-111 and RW-200) along the Schuylkill River. Chronic and acute SWQC for pyrene were not developed in Pennsylvania. The PA Code human health SWQC for pyrene is 830 ug/l. Pyrene concentrations at RW-200 (300 ug/l) and N-111 (160 ug/l) do not exceed the human health SWQC. A screening concentration for chronic exposure to pyrene in fresh water of 0.025 ug/l was derived by Environment Canada which is below the detected pyrene concentration at N-111 and RW-200. Therefore, fate and transport modeling for pyrene was performed.

6. 1,2-dichloroethane RLs were elevated above its groundwater MSC of 5 ug/l at four monitoring well locations (N-58, N-61, N-133 and PZ-506) along the bulkhead, and one location (N-119) in the interior of Drainage Area 2. Wells located down gradient of N-119 did not contain 1,2-dichloroethane above its groundwater MSC and was therefore not modeled. To address the potential for 1,2-dichloroethane to impact surface water QD, SWLOAD and PENTOXSD models were constructed for the four locations along the bulkhead using each RL as the starting concentration.

<u>*Drainage Area 3 Wells*</u>

Drainage Area 3 wells will be addressed through active remediation and therefore were not modeled.

QD and SWLOAD Modeling Results

Drainage Area 1

N-12

The QD modeling result for benzene, pyrene, chrysene and phenanthrene at N-12 indicates potential transport distances ranging from two to eight feet. N-12 is located 575 feet from the property line. These results indicate that there is little potential for these COCs to migrate beyond the property boundary. Individual QD and SWLOAD modeling spreadsheets can be found in Tables J.2 through J.5.

N-101

QD modeling results for chrysene at N-101 indicates potential transport distances of 4 feet. N-101 is located about 350 feet from the northeast property boundary, therefore groundwater at N-101 impacted with chrysene is not likely to migrate to the AOI 8 northeast property boundary.

N-8

This simulation was constructed to address chrysene RL data quality issues. RLs for chrysene were not met in all AOI 8 groundwater analyzed from the July 2008 groundwater sampling event. RLs for chrysene ranged from 5 ug/l to 120 ug/l while the chrysene groundwater MSC is 1.9 ug/l. To address the potential impact of chrysene at concentrations between the groundwater MSC and the maximum RL, a QD model was constructed for N-8 because of its close proximity (25 feet) to the property boundary with a starting concentration of 120 ug/l (maximum RL for chrysene in July 2008 groundwater results). QD modeling results indicate that chrysene would attenuate to a concentration below its MSC within 11 feet from the source. Based on the distances of other site wells from the property boundary chrysene is not predicted to migrate beyond the property boundary above its respective MSC.

Drainage Area 2

Chrysene

Chrysene starting concentrations used in the QD and SWLOAD modeling ranged from 8 ug/l to 120 ug/l for wells N-60, N-111, PZ-503, PZ-505, PZ-506, PZ-507 and RW-200 (Table J.1). Individual QD and SWLOAD modeling spreadsheets can be found in Tables J.6 through J.40. QD modeling results predicted chrysene transport under current aquifer conditions range from less than one to eleven feet before attenuating to its groundwater MSC of 1.9 ug/l. This suggests that chrysene at these locations will not impact the Schuylkill River.

To address RL issues with chrysene, the closest well to the Schuylkill River, PZ-504, was modeled with at starting concentration of 120 ug/l. QD modeling predicts that chrysene will attenuate below its groundwater MSC of 1.9 ug/l within eight feet of PZ-504. This suggests that chrysene in groundwater where the RLs were above the groundwater MSC will not impact the Schuylkill River.

Benzene

As discussed, the benzene concentrations in Drainage Area 2 were divided up into four "zones" based on the benzene isoconcentrations. Starting concentration for benzene in Zones 1 through 4 are, respectively, 300 ug/l (RW-500); 8,700 ug/l (N-61); 2,400 ug/l (PZ-504); and 160 ug/l (PZ-505). QD results for benzene in Zones 1 through 4 indicate that groundwater concentrations will attenuate below its groundwater MSC in 23 feet for Zone 1; 90 feet for Zone 2; 134 feet for Zone 3; and 59 feet for Zone 4. The distances to the Schuylkill River from the most down gradient impacted wells in each zone ranges between 26 to 29 feet. These results suggest that benzene in Zones 2 through 4 have the potential to migrate and reach the Schuylkill River at concentrations greater than the groundwater MSC. Benzene in Zone 1 does not have the potential to discharge to the Schuylkill River above its MSC. SWLOAD was then used to predict groundwater benzene concentration at the Schuylkill River for Zones 1 through 4.

SWLOAD modeling results for Zone 1 predicted a benzene concentration of 2.07 ug/l in groundwater at the Schuylkill River. This concentration does not exceed the groundwater MSC, therefore a PENTOXSD model was not needed for Zone 1.

The SWLOAD model predicted groundwater concentration for benzene in Zone 2 is 947.2 ug/l which exceeds the benzene groundwater MSC. This predicted concentration also exceeds the acute fish, chronic fish and human health SWQC. Therefore the groundwater discharge volume calculated by SWLOAD for Zone 2 was used to create a PENTOXSD model to derive acute fish, chronic fish and human health wasteload allocation for Zone 2.

The SWLOAD model predicted groundwater concentration for benzene in Zone 3 is 676.4 ug/l, which is above the benzene groundwater MSC. This value also exceeds the acute fish, chronic fish and human health SWQC. Therefore the groundwater discharge volume calculated by SWLOAD for Zone 3 was used to create a PENTOXSD model to derive acute fish, chronic fish and human health wasteload allocations for Zone 3.

The SWLOAD model predicted groundwater concentration for benzene in Zone 4 is 29.03 ug/l, which is above the benzene groundwater MSC. It does not exceed the acute or chronic fish SWQC, but does exceed the human health SWQC. Therefore the groundwater discharge volume calculated by SWLOAD for Zone 4 was used to create a PENTOXSD model to derive a human health wasteload allocation for Zone 4.

QD and SWLOAD results for benzene RL problems at N-58 and PZ-506 which used the maximum benzene RL of 10 ug/l, indicates that benzene will attenuate below its MSC (Tables J.1) within 41 feet of N-58 and 11 feet of PZ-506. N-58 is about 55 feet from the Schuylkill River and PZ-506 is 130 feet from the river; therefore, potential benzene impacts at N-58 and PZ-506 are not predicted to reach the river. SWLOAD predicted a benzene concentration in groundwater of 3.96 ug/l at N-58 and <0.001 at PZ-506 at the Schuylkill River.

1,2-Dichloroethane

Elevated RLs for 1,2-dichloroethane in Drainage Area 2 were found at N-58, N-61, N-133 and PZ-506. Because these wells are located close to the Schuylkill River, there is a possibility that groundwater could be impacted with a 1,2-dichloroethane concentration below the RL but above the MSC. This possibility was addressed by constructing QD and SWLOAD models with starting 1,2-dichloroethane concentrations equal to the RL for all four locations (10 ug/l). The groundwater MSC for 1,2-dichloroethane is 5 ug/l. QD and SWLOAD results for N-61, N-133 and PZ-506 indicate that 1,2-dichloroethane in groundwater attenuates to a concentration below the MSC before it reaches the Schuylkill River. 1,2-dichloroethane at N-58 required 75 feet to attenuate below the MSC while the distance to the Schuylkill River is 55 feet. SWLOAD calculated the 1,2-dichloroethane concentration in groundwater adjacent to the Schuylkill River at 5.97 ug/l. Therefore a PENTOXSD simulation was constructed using the SWLOAD calculated groundwater discharge rate for 1,2-dichloroethane at N-58.

Pyrene

Pyrene starting concentrations used in the QD and SWLOAD modeling was 160 ug/l at N-111 and 300 ug/l at RW-200. QD modeling results predicted pyrene transport distance under current aquifer conditions would attenuate to its MSC of 130 ug/l at N-111 in <1 foot and nine feet for RW-200 (Table J.1). This suggests that chrysene at these locations will not impact the Schuylkill River.

Potential Impacts to Surface Water (PENTOXSD) Results

Three PENTOXSD simulations were constructed to address benzene groundwater impacts along the Schuylkill River on the west side of AOI 8. PENTOXSD models were constructed for Zone 2 (N-61, PZ-503), Zone 3 (N-133, PZ-504) and Zone 4 (PZ-505) (Figure J.4). Input parameters for PENTOXSD are summarized in Table J.41. As directed by PADEP the Schuylkill River $Q_{7\text{-}10}$ flow was entered into PENTOXSD as 10% of the actual $Q_{7\text{-}10}$ flow of 101 cubic feet per second (CFS); the harmonic mean flow for the Schuylkill River was entered in PENTOXSD as 10% of the actual harmonic mean flow of 807 CFS. The resulting wasteload allocations for benzene range from a minimum of 417,325 ug/l for human health cancer risk in Zone 3 to a maximum of 11,360,000 ug/l for chronic fish criterion in Zone 2. These results indicate that benzene groundwater concentrations near the bulkhead will not impact the Schuylkill River.

A fifth PENTOXSD model was created to address the elevated RL for 1,2-dichloroethane at N-58 for the July 2008. Flow in the Schuylkill River was identical to the previous PENTOXSD simulations. Input parameters for PENTOXSD are summarized in Table J.41. Wasteload allocations for 1,2-dichloroethane ranged from 165,191.1 ug/l (human health cancer risk level) to 1.04e8 ug/l (chronic fish criterion). PENTOXSD modeling results can be found in Tables J.41 through J.45.

Fate and Transport Modeling Conclusions

Drainage Area 1

Fate and Transport simulations indicate that groundwater concentrations of benzene, chrysene, pyrene and phenanthrene do not pose an unacceptable risk to off-site receptors.

Drainage Area 2

Fate and transport analysis of benzene, chrysene and 1,2-dichloroethane do not pose an unacceptable risk to off-site receptors.

7.3 LNAPL

As described in Appendix G, Sunoco evaluated LNAPL mobility across the site using the API LNAPL model, as a guide for assessing LNAPL volume, mobility, and recoverability across the refinery. Based on the LNAPL types (extremely weathered middle distillates, residual and lubrication oils), updated API Model output results, and recent groundwater gauging activities (May 2011) LNAPL in AOI 8 is stable and immobile.

7.4 Vapor Intrusion into Indoor Air

Occupied areas of AOI 8 include the Boiler House located in the central portion of AOI 8 and the Philadelphia Fire Department building located west of the PGW border. These buildings are shown on Figure B-1 in Appendix B. The Boiler House is operated by Sunoco and regulated by OSHA and there are no known preferential pathways that exist in the immediate area (less than 100 feet) of this occupied building.

Boiler House

The Boiler House building is greater than 100 feet from above mentioned groundwater and soil sample locations which had detections above their respective soil and groundwater MSCs. There are no known preferential pathways connecting these locations to the Boiler House. There is no known LNAPL within 100 feet of the Boiler House. The Boiler House is operated by Sunoco and is included in the indoor air monitoring program and is regulated by OSHA. Indoor air monitoring was performed by Sunoco on September 25, 2008 at the Boiler House for benzene and total VOCs using an Ultra Rae PID. The Ultra Rae is calibrated for benzene and total VOC's using 5 ppm benzene calibration gas and 100 ppm isobutylene calibration gas respectively. The Ultra Rae has a detection limit of 100 parts per billion (ppb) or 0.1 ppm for both benzene and total VOCs. Benzene and total VOCs were not detected in any location during the monitoring event.

Since the site specific standard is being applied, groundwater within some portions of AOI 8 is shallower than 5 feet, underground utilities exist and sampling was not completed below all areas with impervious covers, Sunoco will place a restriction in the UECA covenant for AOI 8 that will require the evaluation of the need for vapor mitigation systems to be installed for any new occupied buildings that will be constructed within AOI 8 as well as any used buildings.

Philadelphia Fire Department Building

The soil gas and indoor air samples collected at the Fire Department building were screened against the applicable indoor air screening criteria in Appendix H of this report. Based on the results, the vapor intrusion into indoor air pathway is incomplete at the Fire Department building.

Jackson Street Sewer

In response to questions No. 5 and 6 of the PADEPs technical response letter (Appendix D), a further evaluation of the sewer as a preferential migration pathway for LNAPL and vapor, was performed by Sunoco in 2009.

In June 2009 Sunoco and Aquaterra collected 24-hour TO-15 summa air gas samples east and west of the water curtain alongside and inside of sewer (Figure 3). The air gas sampling was performed to evaluate possible vapor migration off-site in the residential neighborhood. The air gas sample results were screened against the PADEP residential indoor air screening criteria. The analytical results of the air gas samples indicated that were no benzene detections east of water curtain or off-site in the sewer near residential neighborhoods. Chloroform was above its screening criteria west of water curtain (Manhole No. 1) and off-site in sewer (Manhole No. 6). Concentrations of COCs were below criteria in the background ambient air sample. Methane was detected in Manhole No. 3 west of the water curtain and in Manhole No.6 located in the residential neighborhood.

Sunoco will place a restriction in the UECA covenant for AOI 8 that will require further vapor site characterization activities and/or installation of a vapor mitigation systems for any new/existing occupied buildings within AOI 8.

8.0 SITE CONCEPTUAL MODEL

A preliminary site conceptual model (SCM) for the refinery, including AOI 8, was presented in the CCR. Data collected from the recent site characterization activities performed in AOI 8 were used to refine the SCM for this area. The revised SCM for AOI 8 is described in the following sections:

8.1 Description and Site Use

AOI 8 is the northern-most area of the refinery and is bound by the PGW plant to the south, the Schuylkill River to the west, industrial properties to the north, and urban streets to the east (Figure 1), and encompasses approximately 250 acres.

AOI 8 was an active refinery process area since the early twentieth century with process areas and ASTs. The area also included the former lube, asphalt, soap, and wax plants. The majority of AOI 8 structures were demolished between 1975 and 1980. Subsequent to decommissioning of most of the process areas, a LTU was operated from 1986 through 2000. Currently, the only remaining active facilities in AOI 8 are the asphalt dock, the boiler house, a storm water separator, fuel oil storage, butane and propane storage areas, and loading and unloading facilities. Much of AOI 8 is unimproved and many of the ASTs have been removed. There is one RCRA SWMU located in AOI 8 that was addressed in various stages of previous RCRA investigations as part of the EPA Corrective Action Process. The current, historic uses/investigations and approximate limits of impervious surfaces are depicted on Figure B-1 provided in Appendix B.

AOI 8 is located within a fenced and secured area to prevent unauthorized access. Prior to any work being completed within AOI 8, appropriate work permits, safety and security measures must be approved by Sunoco Refinery personnel. AOI 8 is under the control of Sunoco's health and safety administrative procedures and is regulated by OSHA. Direct contact to site soils (soils greater than two feet beneath the ground surface) is controlled by Sunoco's on-site permit and personal protective equipment (PPE) procedures. The current and future intended use of AOI 8 is non-residential.

8.2 Geology and Hydrogeology

The following summarizes relevant information concerning geology and hydrogeology in AOI 8:

Geology

- Fill materials are present throughout AOI 8.
- In the western portion of AOI 8, the Pleistocene age formations have been eroded and replaced with alluvium. The alluvium is deposited atop bedrock and extends to the central and northern portions of AOI 8, but is absent in the eastern portion. Along the eroded edge (central portion of AOI 8), the alluvium is in direct contact with Trenton Gravel, Lower/Middle Clay, Lower Sand and/or bedrock.
- Trenton Gravel is present in the northern, central and eastern portions of AOI 8 but is absent in the western portion where it has been eroded and replaced with alluvium. The Lower/Middle Clay is present beneath AOI 8 as a wedge that thickens towards the west and the Schuylkill River but is absent between the central and western portions of AOI 8 where it has been eroded and replaced with alluvium. The Lower Sand overlies bedrock in the eastern and central portions of AOI 8, but is absent in the northwestern and western portions where it has been eroded and replaced with alluvium.
- The depth to bedrock beneath AOI 8 increases towards the south.

Hydrogeology

- A groundwater flow divide, trending northwest to southeast, is present in the central portion of AOI 8 in both the shallow and deep groundwater zones. This divide generally corresponds with the eastern extent of the alluvium materials deposited following the erosion and removal of the Pleistocene age deposits. In shallow and intermediate groundwater zones, groundwater on the east side of the divide flows to the northeast and groundwater on the west side of the divide flows to the southwest. In the deep zone, groundwater on the east side of the divide flows to the east and southeast and groundwater on the west side of the divide flows to the southwest.

- The shallow groundwater gradient in the western portion of AOI 8 is relatively flat with some depressions and mounds at isolated locations. Along the western AOI 8 boundary, shallow groundwater flow is more pronounced towards the bulkheads and River.
- The shallow groundwater gradient in the eastern and southern portions of AOI 8 is relatively flat with some depressions and mounds at isolated locations.
- A downward vertical flow gradient exists between the shallow and deep zone as indicated by the groundwater elevations in the following monitoring well pairs: N-3/N-4, N-12/N-13, N-8/N-9, N-18/N-19, N-20/N-21, N-29/N-30, N-38/N-38D, N-43/N-44D, N-47/N-46D and N-51/N-50D. This is consistent with vertical gradients elsewhere in the refinery.

8.3 Compounds of Concern

The following summarizes relevant information concerning COCs in AOI 8:

Shallow Soil

- COCs detected in shallow soil at concentrations above their respective non-residential soil MSCs included: benzene, naphthalene, benzo(a)pyrene and lead.
- Toluene, ethylbenzene, ethylene dibromide, 1,2-dichloroethane, total xylenes, MTBE, cumene, anthracene, pyrene, benzo(g,h,i)perylene, benzo(b)fluoranthene, chrysene, benzo(a)anthracene, phenanthrene and flourene were not detected in shallow soil samples at concentrations above their respective PADEP non-residential soil MSCs.

SWMU 2

- Materials resembling leaded tank bottoms were observed in one boring location (BH-08-05) at SWMU 2. Soil from this boring exhibited a lead concentration below the PADEP non-residential MSC (450 ppm) and was therefore not submitted for TCLP analysis. No other evidence of leaded tank bottom materials were observed in all other soil borings advanced in the area of SWMU 2.

Groundwater

Groundwater samples were collected from monitoring wells that did not contain LNAPL and that were accessible. This included monitoring wells that screened both the shallow/intermediate and lower sand units. The results of the groundwater samples are summarized below by corresponding hydrogeologic zone.

Shallow/Intermediate

- COCs detected in shallow groundwater at concentrations above their respective non-residential groundwater MSCs included: benzene, pyrene, chrysene, phenanthrene, and naphthalene.
- Cumene, toluene, ethylbenzene, ethylene dibromide, xylenes (total), fluorene, MTBE, 1,2-dichoroethane and lead were not detected in shallow groundwater at concentrations above their respective PADEP non-residential MSCs.

Deep (Lower Sand)

- Benzene was detected in three deep (Lower Sand) monitoring wells (N-9, N-21, N-44D) at concentrations slightly above its respective non-residential PADEP MSC.
- Toluene, MTBE, 1,2-dichoroethane, xylenes (total), cumene, ethylbenzene, ethylene dibromide, pyrene, chrysene, phenanthrene, fluorine, naphthalene, and lead were not detected in deep groundwater at concentrations above their respective PADEP non-residential MSCs.

The exposure assessment completed for the COCs above the MSCs is discussed in Section 8.0 of this report.

8.4 LNAPL Distribution and LNAPL Mobility

The following summarizes relevant information concerning LNAPL distribution in AOI 8:

- There are four different types or mixtures of LNAPL were identified in AOI 8 which includes residual oil, lube oil, lube oil/middle distillate mixture, and middle distillate.
- Based on LNAPL modeling, the LNAPL type, degree of weathering, groundwater flow/gradients, presence of a sheet pile/bulk head walls, the absence of LNAPL

in the surrounding monitoring wells, and the occurrence of LNAPL in these monitoring wells over time, LNAPL is considered to be stable and immobile.

8.5 Fate and Transport of COCs

No fate and transport modeling was completed for the soil analytical results since the only potential exposure pathway to soil is by direct contact. The soil-to-groundwater pathway is evaluated through groundwater data.

Drainage Area 1

Fate and Transport simulations indicate that groundwater concentrations of benzene, chrysene, pyrene and phenanthrene do not pose an unacceptable risk to off-site receptors.

Drainage Area 2

Fate and transport analysis of benzene, chrysene and 1,2-dichloroethane do not pose an unacceptable risk to off-site receptors.

Drainage Area 3

Drainage Area 3 wells will be addressed through active remediation. The groundwater and surface water modeling is described in detail in Appendix J.

8.6 Potential Migration Pathways and Site Receptors

The following summarizes potential migration pathways and site receptors for AOI 8.

- AOI 8 is situated within a fenced, secured area to prevent unauthorized access.
- The potential direct contact pathway to soil greater than two feet is deemed incomplete based on Sunoco's existing permitting procedures which protect against exposure to soil encountered in excavations. This pathway may be further evaluated based on site redevelopment.
- The potential direct contact pathway to groundwater is deemed incomplete based on Sunoco's existing permitting procedures which prevent exposure to groundwater that may be encountered in excavations.

- The need for further vapor site characterization activities and/or the installation of vapor mitigation systems for future occupied buildings will be evaluated on a case by case basis.
- The water curtain in the Jackson Street sewer effectively reduces hydrocarbon odors and vapors potentially migrating from the Jackson Street sewer to the surrounding areas.

9.0 HUMAN HEALTH EXPOSURE ASSESSMENT/RISK ASSESSMENT

Based on the current and future intended non-residential site use for AOI 8, an exposure assessment was conducted for compounds that were above the non-residential statewide health standards in AOI 8. Potential human health exposures for the refinery are for an industrial worker scenario. The media evaluated included groundwater, shallow soil, and subsurface soil (greater than two feet below grade).

The potential direct contact pathway for soil (greater than two feet), groundwater and LNAPL under the industrial scenario is eliminated through Sunoco's established excavation procedures, PPE requirements and soil handling procedures described in the CCR. However, because direct contact to shallow soils could occur outside of excavation activities, shallow soil samples were collected in non-paved areas of AOI 8 to assess this potential exposure pathway.

The following table serves as a summary of potential human health exposure pathways that can be reasonably expected under the current and intended future non-residential use for AOI 8. The table lists potentially contaminated media, potential receptors for these media, and a summary of whether any potentially complete exposure pathways exist at AOI 8 from the media to these receptors.

Exposure Pathway Evaluation Summary

Contaminated Media	Residents	Workers	Day Care	Construction	Trespassers	Recreation	Food
Groundwater	NA	No(1)	NA	No (2)	No	NA	NA
Air (indoor)	NA	No (3)	NA	No(3)	No	NA	NA
Soil <2 feet bgs.	NA	Yes	NA	Yes	No	NA	NA
Soil >2 feet bgs.	NA	No(4)	NA	No(4)	No	NA	NA
Surface Water	NA	No(5)	NA	No(5)	Na	NA	NA
Sediment	NA	NA	NA	NA	Na	NA	NA
LNAPL	NA	No(1)	NA	No (2)	Na	NA	NA

Notes:

(1) No complete groundwater or LNAPL pathways exist for workers that are not addressed through on-site permitting procedures and PPE.
(2) No complete groundwater or LNAPL pathway exists for construction workers that are not addressed through on-site permitting procedures and PPE.
(3) No current complete pathway to indoor air exists based on the evaluation described in Section 6.5.
(4) No complete pathway exists for site soil >2 feet deep that are not addressed through on-site permitting procedures and PPE.
(5) No complete pathway exists for surface water or sediment that is not addressed through on-site permitting procedures and PPE.
Na - Not applicable
No - No potential complete exposure pathway
Yes – Potential complete exposure pathway

A more detailed evaluation of each of these potential human health exposure pathways is presented in the following sections by media.

9.1 Surface Water

There are no surface water features located within AOI 8. The nearest surface water body to AOI 8 is the Schuylkill River which borders the western site boundary (Figure 2). A sheet pile wall and bulkhead are located along the western boundary of the site. Shallow/intermediate groundwater interaction with surface water is limited by the above referenced sheet pile wall and bulkhead.

Based on the location of the sheet pile wall and bulkhead, groundwater flow, and the results of the groundwater modeling for monitoring wells where groundwater samples were above the groundwater MSCs, none of the constituents detected in groundwater will cause an in-stream violation of surface water quality criteria for the Schuylkill River.

9.2 Shallow Soils (0-2 Feet Below Grade)

The soil-to-groundwater pathway is being addressed through the groundwater pathway discussed in Section 9.3.

Direct Contact Exposure

Shallow soil samples collected and analyzed as part of the AOI 8 characterization activities exhibited concentrations of benzene, benzo(a)pyrene, naphthalene and lead above their respective non-residential direct contact MSCs. In accordance with Section IV of the PADEP's Technical Guidance Manual, site-specific standards for lead and benzene were calculated using PADEP default intake parameters for an onsite worker and a risk level of 10^{-4}. For calculating a site-specific standard for on-site workers exposed to lead, Sunoco used the Society of Environmental Geochemistry and Health (SEGH) model used by PADEP to develop the non-residential soil MSCs.

The site-specific standards for the organic compounds (calculated in Appendix K, Tables F-1 through F-4) are as follows:

Compound	Calculated Site-Specific Standard (mg/kg)
Benzene	2,160
Naphthalene	56,780
Benzo(a)pyrene	109
Lead	1,708

The site-specific screening level for benzene was calculated for inhalation based on the calculation specified in 25 Pa. Code § 250.307(b), and for naphthalene and benzo(a)pyrene for ingestion based on the calculations specified in 25 Pa. Code § 250.306(b). These calculations used the PADEP's default parameters and an updated target risk level of 1E-4, in consideration of the site-specific conditions (PADEP's default target risk level is 1E-5).

As presented in Table F-1 through F-4, based on the revised target risk level, the derived site-specific standards for benzene, naphthalene and benzo(a)pyrene are calculated for an onsite worker and are consistent with the values used in the previous AOI SCRs prepared for the refinery. Concentrations of benzene, naphthalene and benzo(a)pyrene detected in the shallow soil samples collected in AOI 8 are below the site-specific standards and, therefore, risk to an on-site worker due to exposure is considered to be within the acceptable Act 2 range.

The site-specific standard for lead based on the SEGH model presented in Appendix K was calculated to be 1,708 mg/kg for a worker. The site-specific screening level for lead was calculated for ingestion. As presented in 25 Pa. Code § 250.306(e), Appendix A, Table 7, the non-residential soil screening value for lead is based on the method presented in the report 'The Society for Environmental Geochemistry and Health (SEGH) Task Force Approach to the Assessment of Lead in Soil' (Wixson, 1991). The model used by the PADEP and developed by SEGH was also used to calculate the site specific criterion for the refinery. Based on the SEGH model and PADEP's default parameters, PADEP's non-residential direct contact MSC default value for lead in shallow soil is 1,000 mg/kg. To develop a site-specific criterion for lead, some of the parameters used by the PADEP were updated in consideration of site-specific conditions and updated lead data collected from recent studies.

As presented in Table F-4 of Appendix K, based on the revised parameters, the derived site-specific standard for lead in soil is 1,708 mg/kg for a refinery worker. Concentrations of lead detected in the shallow soil samples collected in AOI 8 are below the site-specific standard and, therefore, risk to an on-site worker due to exposure to lead is considered to be within the acceptable Act 2 range.

In addition to calculating the site-specific standards for benzene, naphthalene, benzo(a)pyrene, and lead, the cumulative risk of exposure was also calculated. Lead exposure is dependent on the blood/lead concentration and not risk based; therefore, lead could not be incorporated into the cumulative risk calculation.

The cumulative hazard index is the combined index for exposure to non-carcinogenic compounds (naphthalene) and should not exceed 1. As presented in Table F-5 of Appendix K, the cumulative hazard index for exposure to the non-carcinogenic compounds is less than the PADEP's requirement of 1.0 and therefore no remedies are required for AOI 8 to address exposure to non-carcinogenic compounds.

The total cumulative risk is the combined risk of exposure to the concentrations of carcinogenic compounds (benzene and benzo(a)pyrene) and, in accordance with the TGM, the total cumulative risk should not exceed 10^{-4}. As presented in Table F-5, the total cumulative risk of exposure to the carcinogenic compounds in AOI 8 is 1.69^{E-4}, and exceeds the acceptable risk limit. Potential exposure to carcinogenic compounds in the areas of N-99 and N-134 (which have the highest concentrations of benzo(a)pyrene), will be addressed by Sunoco through implementation of a remedy which will either remediate or eliminate the potential pathway to onsite workers. Once these areas are addressed as will be proposed in the Cleanup Plan, the total cumulative risk will be below 10^{-4}.

9.3 Groundwater

Results of the groundwater sampling indicated COCs at concentrations above their respective non-residential groundwater MSCs, included benzene, pyrene, chrysene, phenanthrene, and naphthalene. Concentrations of these COCs to impact off-site receptors are limited due to the direction of groundwater flow. In addition, pyrene, chrysene, phenanthrene and naphthalene groundwater impacts do not migrate very far (tens of feet) from their respective sources; this is due primarily to a strong tendency for these compounds to partition to soils during transport. Based on the QD, SWLOAD and PENTOXSD fate and transport analysis, concentrations of the above mentioned COCs are not expected to exceed the groundwater MSCs at the site boundary or have an unacceptable impact on site receptors (Schuylkill River to the west and/or residential areas to the east).

Excavations in AOI 8 are governed by Sunoco's permitting procedures which protect against potential exposures to groundwater that could be encountered in an excavation. Also, there are no complete direct contact exposure pathways for groundwater within AOI 8 because of on-site refinery safety procedures and required PPE. Previous investigations and well searches verified that no wells located within 1.5 miles of the refinery are used for drinking water or agricultural use.

9.4 LNAPL

There are no complete direct contact exposure pathways for LNAPL within AOI 8 because of on-site permitting procedures and required PPE.

9.5 Vapor

Based on the results of the vapor intrusion assessment completed at the Philadelphia Fire Department Building indicated that concentrations of COCs are below the indoor air screening criteria.

Based on the results of the assessment activities completed at the Jackson Street Sewer, the water curtain is successfully reducing hydrocarbon odors and vapors that potentially could migrate from the Jackson Street sewer to the surrounding areas.

Further evaluation (i.e. soil gas samples) will be completed to assess the impact to indoor air or vapor mitigation systems will be installed in any occupied buildings constructed/used at the refinery dependent upon site redevelopment.

10.0 ECOLOGICAL ASSESSMENT

The majority of AOI 8 is covered with soil and gravel. Some areas are covered by impervious surfaces as shown in Appendix B. The soil and gravel-covered portions of AOI 8 are not likely to serve as a breeding area, migratory stopover, or primary habitat for wildlife. In 2011, a survey of endangered, threatened and special concern wildlife was conducted by submitting a request to the Pennsylvania Natural Diversity Inventory (PNDI) data base. No endangered, threatened or special concern wildlife was identified in AOI 8 using these maps or during historical investigations. Based on this information, there are no terrestrial ecological receptors of concern for AOI 8 and no related assessment was necessary.

No surface water features are located in AOI 8. The nearest surface water body to AOI 8 is the Schuylkill River which borders the western boundary. Sheet pile and wooden bulkheads are present between AOI 8 and the Schuylkill River as illustrated in Figure 2. Groundwater interaction with surface water/sediment is limited by the above-referenced walls. Based on QD, SWLOAD and PENTOXSD fate and transport analysis, the presence of impacted groundwater in AOI 8 should not pose a threat to surface water.

11.0 COMMUNITY RELATION ACTIVITIES

A Community Relation Plan (CRP) that includes public involvement with local residents to inform them of the anticipated investigations and remediation activities was completed as part of the NIR submittal in 2006. The purpose of this CRP is to provide a mechanism for the community, government officials, and other interested or affected citizens to be informed of on-site activities related to the investigation activities at the Site. This plan incorporates aspects of public involvement under both PADEP's Act 2 program and EPA's RCRA Corrective Action program. This report and future Act 2 reports will include the appropriate municipal and public notices in accordance with the provisions of Act 2. Notices will be published in the Pennsylvania Bulletin and a summary of the notice will appear in a local newspaper. As part of the CRP, Sunoco intends to hold an initial public meeting in the city of Philadelphia to present the strategy and give status updates of the project at the CAP meeting on an annual basis.

A copy of the NIR and the Act 2 report notifications for this SCR/RIR are included in Appendix A.

12.0 CONCLUSIONS AND RECOMMENDATIONS

Based on the results of the completed activities, the following conclusions and recommendations have been developed for AOI 8:

<u>Soil Outside of SWMU 2</u>

- Concentrations of benzene, naphthalene, benzo(a)pyrene and lead detected in shallow soil samples collected in AOI 8 were above their respective non-residential soil MSCs; however they were below the calculated site-specific standards. The total cumulative risk of exposure to the carcinogenic compounds in AOI 8 is $1.69E^{-4}$, and exceeds the acceptable risk limit. Potential exposure to carcinogenic compounds in the areas of N-99 and N-134 (which have the highest concentrations of benzo(a)pyrene), will be addressed by Sunoco through implementation of a remedy which will either remediate or eliminate the potential pathway to onsite workers. As part of the Cleanup Plan for AOI 8, these areas will be addressed and the total cumulative risk will be below 10^{-4}. Selected soil samples of ethylene dibromide will also be collected due to the RLs exceeding the MSCs and the results will be reported in the Cleanup Plan.
- With regard to the potential direct-contact pathway to deeper soil (i.e., greater than 2 feet deep) and the soil-to-groundwater pathway, the direct contact pathway to soil greater than 2 feet beneath the ground surface at the refinery is incomplete because of on-site procedures and PPE requirements that protect onsite workers from exposure. This pathway may be further evaluated under redevelopment scenarios. The soil-to-groundwater pathway was evaluated using shallow groundwater data as is discussed below.

<u>Groundwater</u>

- Five COCs (benzene, pyrene, chrysene, phenanthrene, and naphthalene) were detected in groundwater during the July 2008 groundwater sampling event at concentrations above their respective used-aquifer, non-residential groundwater MSCs. Based on QD, SWLOAD, and PENTOXD fate and transport simulations, the presence of the bulkhead/sheet pile wall, groundwater flow direction and the proposed re-start of remedial activities along the PGW border, concentrations of the above mentioned COCs are not expected to exceed the groundwater MSCs at the site boundary and or affect site receptors (Schuylkill River to the west and/or residential areas to the east).
- Chrysene, 1,2,4-trimethylbenzene, and 1,3,5-trimethylbenzene will be evaluated in select wells and the results will be documented in the Cleanup Plan due to the RL exceedances of the groundwater MSCs. Based on the conservative fate and transport modeling it is not expected that these results will alter the results of this RIR.

<u>Vapor</u>

The results of the vapor intrusion screening evaluation using the PADEP guidance indicated:

- Results of the soil gas and indoor air sampling completed at the Philadelphia Fire Department Building indicated that concentrations of COCs are below the indoor air screening criteria.
- The Jackson Street Sewer analytical results indicated that indoor air exceedances were detected west of the water curtain, but not to the east, indicating that the water curtain is effectively controlling vapor migration from the sewer. Although methane was detected east of the water curtain, it is associated with a background source.
- The need for further vapor site characterization activities and/or the installation of vapor mitigation systems for future/existing occupied buildings will be performed per the UECA covenant as part of redevelopment activities, as necessary.

<u>LNAPL</u>

- The horizontal extent of the LNAPL plume relative to the site boundaries has been delineated and mobility of the identified LNAPL is low.

- Based on the remedial system evaluations performed on the Jackson Street Sewer and the Bulkhead systems, Sunoco intends to keep the systems offline. The Jackson Street Sewer outfall will continue to be monitored to confirm the lack of LNAPL presence.
- Impacted groundwater and LNAPL (lube oil and residual oil) along the PGW border in Drainage Area 3 will be addressed by the existing PGW Border Total Fluids Recovery System. The effectiveness of the PGW Border Total Fluids Recovery system and the need to expand the system is being further evaluated by Sunoco. Updates and proposed modifications to the existing remediation system will be provided in the quarterly reports or the Cleanup Plan prepared for the refinery.
- There are no complete direct contact exposure pathways for LNAPL within AOI 8 because of on-site permitting procedures and required PPE.

RCRA SWMUs

- No leaded tank bottom materials were identified meeting all of the established criteria in AOI 8. Therefore, Sunoco is requesting a comfort letter for SWMU 2 in AOI 8 from EPA.

13.0 SCHEDULE

The proposed schedule for future Site activities is:

- Submittal of a Cleanup Plan following PADEP approval of the SCR/RIR and in concert with redevelopment plans;
- Submittal of a Final Report; and
- Continue quarterly monitoring activities and reports.

14.0 SIGNATURES

The following parties are participating in the remediation at this time and are seeking relief from liability under Act 2 of 1995:

James Oppenheim
Sunoco Inc. (R&M)

This Act 2 RIR has been prepared in accordance with the final provisions of Act 2 and the June 8, 2002 Land Recycling Program Technical Guidance Manual.

15.0 REFERENCES

Groundwater Resources of the Coastal Plain Area of Southeastern Pennsylvania. Greenman, Topographic and Geologic Survey, Bulletin W-13, 375 pp., David W., Rima, Donald R., Lockwood, William N. and Meisler, Harold. 1961.

Simulation of Ground-Water Flow in the Lower Sand Unit of the Potomac-Raritan-Magothy Aquifer System, Philadelphia, Pennsylvania, U.S. Geological Survey, Water-Resources Investigations Report 86-4055, Sloto, R. A., 1988.

RCRA Facility Investigation Work Plan, Philadelphia Refinery, Sun Refining and Marketing Company, Philadelphia Pennsylvania, CHM2HILL, May 1991.

The Atlantic Lead Weathering Pad Final Closure Report, Sun Refining and marketing Company, Atlantic Refining and marketing Corporation, Philadelphia Refinery, K.W. Brown & Associates, Inc., March 1991.

Comprehensive Remedial Plan, Philadelphia Refinery, Sun Company (R&M), ENSR Consulting and Engineering, September 1993.

Remedial Action Plan for the NO.3 Tank Farm Separator, Sun Company (R&M), Philadelphia Refinery, ENSR Consulting and Engineering, October 1993.

Remedial Action Plan for the North Yard Bulkhead, Sun Company (R&M), Philadelphia Refinery, ENSR Consulting and Engineering, October 1993.

Remedial Action Plan for the North Yard Southern Property Boundary, Sun Company (R&M), Philadelphia Refinery, ENSR Consulting and Engineering, December 1993.

Ground Water Remediation Project Data Book, Volumes 1 and 2, 1995 Brown & Root, Inc.

Corrective Measures Study Work Plan, Sun Company, Inc. (R&M), Philadelphia, PA, ENSR Consulting and Engineering, April 1997.

Landfarm Treatment Unit Closure Activation Report, Philadelphia Refinery Point Breeze

Processing Area, Blazosky Associates Inc, November 2000.

Simulation of Ground-Water Flow in the Potomac-Raritan-Magothy Aquifer System Near the Defense Supply Center Philadelphia, and the Point Breeze Refinery, Southern Philadelphia County, Pennsylvania, Water-Resources Investigations Report 01-4218, 20 pp, Schreffler, C. L., U.S. Department of the Interior, 2001.

Amended Closure Plan, Sunoco, Inc. Philadelphia Refinery, Point Breeze Processing Area, Land Treatment Unit, Blazosky Associates, Inc., November 1988 and amended November 2002 and May 2004.

Consent Order and Agreement by and between the Commonwealth of Pennsylvania, Department of Environmental Protection, Atlantic Refining & Marketing Corporation and Sunoco Company, Inc. (R&M), August 1996, and amended December 2000 and July 2004.

Amended Post-Closure Plan, Sunoco, Inc. Philadelphia Refinery, Point Breeze Processing Area, Land Treatment Unit, Blazosky Associates, Inc., November 1988 and amended June 2003 and May 2004.

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U.S. Department of the Interior, Geohydrology and Ground-Water Resources of Philadelphia, Pennsylvania, U.S. Geological Survey, Water-Supply Paper 2346.

Current Conditions Report and Comprehensive Remedial Plan, Sunoco Inc., Philadelphia, PA, prepared by Langan Engineering and Environmental Services June 30, 2004.